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NEW OR INTERESTING PHILIPPINE FERNS, VII[1]

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NINE PLATES

The ferns here described or discussed were collected on Mount Matutum, or attracted attention in connection with the determination of the ferns collected there, or in the preparation of a second century of the author's Pteridophyta Philippinensia Exsiccata. Mount Matutum is an extinct volcano standing above Sarangani Bay, in southeastern Mindanao. It is the farthest south of the high mountains of the Philippines. As was to be expected, its vegetation was found to be similar to that of Mount Apo. The two days spent in the ascent and return showed it to be one of the richest collecting grounds in the Archipelago.

In view of the apparently general opinion that the Philippine fern flora has been well studied, it is in order to note that a really large number of species already in herbaria are still undescribed.

OSMUNDA HERBACEA Copeland sp. nov.

Plenasium, stipite 70 cm alto, 1 cm crasso, basi invisa alibi glabro; fronde 1.5 m alta, sursum sterile; pinnis ca. 8 cm longis, 8 mm altis, cum stipitulis usque ad 8 mm longis, sterilibus grosse sed haud argute serratis, sinubus rotundatis, dentibus serrulatis, herbaceis, fertilibus pinnatis.

MINDANAO, Mount Matutum, *Copeland s. n.*, May 1, 1917.

A single fertile frond was found, and this suffered in the press, nearly all pinnæ separating from the rachis. Even with

[1] The sixth paper with this title appeared in Philip. Journ. Sci. § C 7 (1912) 53.

the poor and scant material, the texture, the rounded sinuses, and the serrulate teeth distinguish it from the only other species otherwise like it, *O. banksiifolia.* Hooker, Exotic Ferns, 9, complained that the species of *Plenasium* were ill defined; but this seems to me to be true only of his own *O. vachelii,* which is at least very close to *O. javanica. Osmunda banksiifolia* and *O. bromeliaefolia* are as distinct as species need be.

Why is *O. cinnamomea* not known as *O. bipinnata* Linnæus—assuming that they are synonyms? The latter name has page priority. There is a rule—which is contrary to the principles underlying the whole body of rules—against any page priority, but such a rule is inapplicable to species, and in questions in which specific names alone are involved; no such thing as a *species conservanda* has ever been proposed. No present authority is recognized as competent to maintain a second specific name as against a first one, though the difference be only in position on the same page.

GLEICHENIA PELTOPHORA Copeland sp. nov. Plate 1.

Eugleichenia, rhizomate late repente, 1.5–2 mm crasso, lignoso, glabrescente; stipitibus remotis, usque ad 60 cm altis, castaneis, superne applanatis, inferne rotundatis, sparse punctulatis, glabris vel mox grabrescentibus: pseudo-pinnis oppositis, 1-vel pluriparibus, infimis rarius ut rami frondium compositis, plerumque definitis, usque ad 30 cm longis, anguste lanceolatis, abrupte caudatis, deorsum angustatis, rhachibus glabrescentibus superne late sulcatis; pinnulis infimis remotis et diminutis, medialibus permultis erecto-patentibus vulgo 4 cm longis, 2–3 cm latis, sessilibus, fere ad costam glabrescentem pinnatifidis; segmentis confertis, oblongo-semiorbicularibus, marginibus leviter deflexis, in vetustate cucullatis, coriaceis, superne nigro-fuscis, inferne glaucis et paleis magnis peltatis orbicularibus castaneis pallidius marginatis ornatis; soris solitariis, profunde immersis, sporangiis plerumque 4, flavis.

MINDANAO, Mount Matutum, altitude 1,600 meters, May 1, 1917.

Nearest to the South African *G. polypodioides;* among Malayan species, to *G. vulcanica,* which has more moderately immersed sori. It approaches *G. longissima* as described by Blume, but the conspicuous peltate scales distinguish it very clearly from all other species. These are commonly 5 to 8 to the segment, and occupy about half of its surface. This is a remarkably large plant, for an *Eugleichenia.*

CYATHEA LEYTENSIS Copeland.

Cyathea leytensis COPELAND, Philip. Journ. Sci. 38 (1929) 131.

MINDANAO, Mount Matutum, *Copeland P. P. E. 187.*

Previously known only by the type collection, from Leyte. The Matutum specimen is exactly like the type in its white-ciliate paleæ and pale tawny indusia. The secondary pinnules are nearly entire, as contrasted with those conspicuously crenate on the type, which may be correlated with the fact that the Matutum plant is much less copiously fruiting. The trunk is 5 cm in diameter, and very hard. The stipe bears very slender tawny paleæ at the base. It is everywhere densely furfuraceous, and black under the fuzz. Within 10 cm of the base are one or two dwarfed pinnæ, about 6 cm long. The next pinnæ, 30 cm long and fully developed, though shorter than those still higher up, are 40 cm removed from the little basal ones. It is still another 40 cm up to the real body of the frond. Thus the ample expanded crown of fronds has its main laminar development begin about a meter out from the center, but the small lower pinnæ make some use of the central area. The stipes and the lower part of the rachises are beset with very sharp spines, 2 to 3 mm long; whatever animals of any size might menace the foliage must be kept away effectively by this long spiny bar.

DRYOPTERIS GYMNOCARPA Copeland.

This species was described from small plants collected by Elmer on Mount Apo, Mindanao. From the Mountain Province, northern Luzon, have come specimens which seems to represent it; namely, an ample collection now distributed as *Pteridophyta Philippinensia Exiccata No. 160;* a single sheet, collected above Bagnen, in Lepanto, in 1905; and a sheet labeled *Athyrium macrocarpum, Philippine Plants No. 966,* collected in Benguet by Merrill. Their height runs up to 30 centimeters, with free pinnæ correspondingly more numerous than in *D. gymnocarpa* as described. They are much smaller and narrower than *D. africana.* The young sporangia of the Benguet specimens are freely setuliferous, as in *Dryopteris somai* Hayata, of Formosa.

DRYOPTERIS RIZALENSIS Christ.

The type of this species is from San Ramon, Zamboanga Province; the Rizal plant, although it provided the specific name, being "a smaller form," and thus, at least, not typical. The type was collected at 475 meters altitude, and I have specimens from 800, 1,000, and 1,050 meters. The indusium, described as "reniformi flaccido griseo mox evanido," is wonderfully beset with

short, thick, white trichomes, becoming tawny with age. These stand almost contiguous along the margin, and are far from sparse all over the outer surface. It is persistent, and becomes "evanido" only as it is crumpled together by the growth of the sporangia, so that in full fruit only some of the ciliate margin remains visible between them. The Mount Apo plant which has been cited as this species is aberrant, being larger and with less bristly axes.

Dryopteris preslii (Baker) O. K., known only by the type collection, *Cuming 255*, is very near to *D. rizalensis*. Christ seems not to have had this plant, and to have mistaken another fern for it, when he associated it with *"Phegopteris obscura."* As compared with *D. rizalensis*, it is more finely but less densely aciculate, the intermediate pinnæ are few and relatively broad, and the trichomes on the indusium are red, glandular, and clavate.

Another nearly related fern, also present at San Ramon, can be called *D. aciculata* (Baker) C. Chr. It is perfectly identical with specimens from Sarawak, but intermediate in stature and dissection between typical *D. aciculata* and *D. sarawakensis* (Baker) v. A. v. R. If these two are not separable, the latter is (as between the two) the valid name.

DRYOPTERIS GRACILIS Copeland sp. nov.

D. Beddomei affinis, stipitibus remotis et frondibus graciliori-bus distincta; rhizomate latissime repente, 1–1.5 mm crasso, nigrescente, paleis sparsis appressis castaneis anguste ovatis 1–2 mm longis deciduis vestito, glabrescente; stipitibus inter se 1–5 cm remotis, basibus nigris decidue paleaceis, sursum stramineis glabris, 5–12 cm altis, gracillimis; fronde lineare, usque ad 30 cm longa et 3 cm lata, utrinque longissime attenuata, bipinnatifida, apice acuminata pinnatifida, pinnis usque ad 40-paribus, infimis remotis ad vestigia plerumque trifida 1–2 mm longa reductis, rhachi sparse albo-pilosa; pinnis medialibus hori-zontalibus, sessilibus, basibus dilatatis 5 mm latis, obtusis, pro-funde pinnatifidis, papyraceis, superne obscuris fere glabris, inferne ad costas venasque setis gracillimis 0.5–1 mm longis albis ornatis, sparse ciliatis; segmentis 1–1.5 mm latis, majoribus ad apices crenato-dentatis; venulis 2- vel 3-paribus, simplicibus; soris ad venulas inferiores subapicalibus; indusiis glabris, mox evanidis.

MINDANAO, Mount Apo, altitude 1,700 to 1,800 meters, *Elmer 11520* (type), *11592*.

Distributed as *D. beddomei* (Baker) O. K., a species common in the highlands of northern Luzon, and otherwise unknown in the Philippines. So far as explicit published descriptions go, *D. beddomei* would include this fern, but they are distinct enough in appearance. I have no specimens of it from India; but it was described by Beddome (Ferns of Southern India, p. 38) as having the fronds crowded. The fern of southern China, referred to by both Beddome and Baker, has them clustered, however long the nonfrondiferous portions of the rhizome may be, as is true also of all Benguet specimens.

DRYOPTERIS ELMERORUM Copeland sp. nov. Plate 2.

Nephrodium rhizomate breve, repente vel adscendente, valido; stipitibus caespitosis, 20–35 cm altis, basi 3 mm crassis paleis castaneis lanceolatis 3 mm longis ciliatis vestitis, sursum rhachibusque dense minute pubescentibus gracilescentibus; fronde 20–30 cm alta, 12 cm lata, pinnata, apice 10 cm longa pinnatifida valde acuminata; pinnis ca. 9-paribus, supremis adnatis, aliis stipitulatis stipitulis 1–2 mm longis, pleresque cordatis, infimis plus minus deflexis basi rotundatis, omnibus breviter acuminatis, versus apices serrulatis, alibi leviter (¼ ad costam) lobatis, lobis 3 mm latis, falcato-rotundatis, ob excisionem inter apices venularum dentatis, papyraceis, superne setuliferis, inferne ad costas setis parvis densis et majoribus paucis ornatis, ad venas venulasque sat dense setuliferis; venulis ca. 6-paribus, ca. 3-paribus anastomosantibus, inferne praestantibus, vena secundaria ad sinus excurrente ob laminam hic infraflexam praestantissima; soris supramedialibus, indusiis orbiculari-reniformibus bullatis minute pubescentibus persistentibus obtectis.

MINDANAO, San Ramon, altitude 1,000 meters, November, 1911.

This very distinct species is named in joint honor of the two botanists most responsible for our knowledge of the Philippine flora—Elmer D. Merrill, my companion when it was collected, and A. D. E. Elmer.

DRYOPTERIS PILOSIUSCULA (Zipp.) C. Chr.

LUZON, Tayabas Province, Infanta, *C. B. Robinson, Bu. Sci. 9455,* August, 1909.

Identical with specimens from Java, determined by Christensen. Hitherto known only from Java.

DRYOPTERIS XIPHIOIDES Christ.

Dryopteris xiphioides CHRIST, Philip. Journ. Sci. 2 § C (1907) 201.

This species was apparently described from a single specimen. It belongs in a group in which, if one be disposed to make fine

distinctions, there is no limit to the number of species. The type material has the most ample fronds, among all which I refer to this species; it is rather old and described as exindusiate. Better specimens show a vestigial indusium, without definite form. The sori are basal on the veinlets, commonly paired, and often confluent. The lateral pinnæ of most specimens are strongly auricled on the upper side, and more slender than on the type. As rare variants, the terminal leaflet may be pinnately lobed; and the lowest pair of pinnæ may be dilated above the base, suggesting *D. diversiloba.* Including all of these forms, we have an ill-definable species; but this is better than describing each plant as distinct. I have a number of specimens from Binalui, a few miles from the type locality, and a single one from Lanao, collected by Mrs. Clemens. It is related to *D. merrillii* Christ, which is perhaps too nearly related to *D. hosei.*

DRYOPTERIS TEPHROPHYLLA Copeland sp. nov.

Sp. D. spenceri similis et affinis, fronde minore et tenuiore, soris vix elongatis, indusio parvo inconspicuo distincta; rhizomate breve, repente vel suberecto, paleis castaneis ovatis lanceolatisve acuminatis usque ad 3 mm longis vestito; stipitibus stramineis, brevibus; fronde 30 cm, rarius usque ad 45 cm, alta, supra mediam 7–8 cm lata, utrinque sensim angustata et acuminata, rhachi pilis pallidis 1–1.5 mm longis sparsis ornata et brevissime dense pubescente, parte superiore ca. 10 cm longa pinnato-lobata, lobis ovatis subfalcatis apice rotundatis; pinnis sessilibus vel subsessilibus, maximis vix ultra 4 cm longis, 12–14 mm latis, subfalcatis, obtusis vel subacutis, basi truncatis vel bassiscopice cordatis, crenatis, sparsim ciliatis, tenuiter herbaceis, superne griseis pilis sparsis 1 mm longis ad venas ornatis, lamina decidue inconspicue pubescente, inferne pallide viridibus ad costas venasque pilis minoribus adspersis; pinnis inferioribus gradatim ad auriculas basales minutas triangulares reductis; venulis in pinnis majoribus saepius 2-paribus anastomosantibus, in apice pinnatifida plerumque areolas paucas irregulares more Haplodictyi efficientibus; soris medialibus, non vel vix elongatis; indusiis inconspicuis primo pilis paucis ornatis.

MINDANAO, San Ramon, altitude about 800 meters, type collected by E. B. C., April, 1905; collected again in the same vicinity in 1907 and 1911.

The type of this species is the specimen referred to by Christ, Philip. Journ. Sci. 2 § C (1907) 206, as distinguishable from *D. spenceri* "by its shorter and more numerous pinnae;" its original

label bears Christ's notations as "Nephrodium canescens (Bl.) var. nephrodiiformis Chr." and "N. Spenceri Copel. var." It is very distinct from the former, but so suggestive of an immature form of the latter that it is only as material of both has accumulated that I have become convinced of its stable distinctness. They differ constantly in size, texture, and color. The pinnæ of *D. spenceri* reach a size of 10 by 2.5 centimeters, and the larger ones are decidedly acuminate. Although the ampleness of lamina might be expected to carry with it greater complexity of venation, examination of many fronds has exposed only one or two of the supplementary areolæ, which are constantly present on well-grown fronds of *D. tephrophylla.* A remarkable feature of *D. spenceri,* as to which its diagnosis was singularly in error, is the form of sorus and indusium. These are not uniform, but are commonly elongate, sometimes more than twice as long as broad, and not uncommonly unequal-sided, of the typical *Athyrium* form. The indusium is persistent and strongly hispid.

DRYOPTERIS DIVERSILOBA Christ.

Dryopteris diversiloba (Presl) CHRIST, Philip. Journ. Sci. 2 § C (1907) 199, as "n. subsp.," and regardless of citation of specimens.
Nephrodium diversilobum PRESL, Epimeliae Bot. 47.

This species was described unmistakably by Presl, who cited *Cuming 51* and *102* as typifying and representing it. The same two numbers, and only these, are cited with the brief diagnosis of *Goniopteris asymmetrica* Fée. Cuming's numbers were notoriously mixed, but the evidence of the specimens is needed before it is easy to believe that two different ferns were both included under both numbers. As Fée evidently published his Genera Filicum before seeing Presl's Epimeliae, he might naturally have described the same fern independently; and my only reason for doubting that he did this is his expression, "segmentis in apice frondium inaequalibus," which does not apply to *D. diversiloba,* but does to a distinct, commoner Philippine species, otherwise perhaps nameless. Christ mistook the other species for *D. diversiloba* in publishing this combination; but he had previously indentified it for me using Fée's name, and must have returned to this view when he made the combination *Dryopteris asymmetrica,* Geographic der Farne, p. 226. His only mention of *Cuming 51,* the type collection of both *Nephrodium diversilobum* and *Goniopteris asymmetrica,* is in connection with his own *Dryopteris acromanes.*

These observations do not clarify this group, but they help to define the difficulties. The mixture under Cuming's numbers makes dependence on their citation impracticable, except as conformity of specimen and complete description insures indentity; as thus I know *Nephrodium diversilobum.* Whether or not the commoner species is *Goniopteris asymmetrica* can be known only after consultation of Fée's type. The moderns have added to the difficulty of selecting names in the group, by Christ's description of an indusium as wanting, and five lines later as peltate [Ann. Jard. Bot. Buit. **15** (1897) 131], and van Alderwerelt's resurrection of the specific name *blumei. Nephrodium blumei* J. Smith was a nomen nudum. A description was provided by Mettenius, as *Aspidium blumei.* The fern typifying it had already been endowed by van Alderwerelt with one useless new combination, as *Pleocnemia heterophylla,* Malayan Ferns, p. 171 (if there be a genus *Pleocnemia,* this is nothing like it), before he came to *Dryopteris blumei, ibid.,* p. 231. We can discard this name, positively. *Nephrodium subdimorphum* Christ may be a valid species; once published, the author seems to have forgotten it, for it is unmentioned in his Farnflora von Celebes and his Philippine Species of Dryopteris. I doubt the occurrence of *D. canescens* in the Philippines.

DRYOPTERIS DIMINUTA Copeland sp. nov.

"Meniscium" gregis D. canescentis; rhizomate repente, 1 mm crasso, paleis castaneis lanceolatis 2 mm longis vestito; stipitibus seriatis haud remotis, pubescentibus, 1–3 cm altis; fronde sterile 3–6 cm longa, pinnata, foliola apicale 2–4 cm longa, 1.5 cm lata, obtusa, lobata, herbacea, superne minute setosa, venis inferne setis persistentioribus majoribus donatis, venulis utroque latere venae 3 vel 4, quarum 1 vel 2 anastomosantibus; pinnis utroque latere ca. 2, stipitulatis, 3–8 mm longis, plus minus orbicularibus sed variabilibus, venulis interdum liberis; fronde fertile graciliore et longius stipitata, aliter conforme; soris elongatis interdum confluentibus, exindusiatis; sporangiis setiferis.

MINDANAO, San Ramon, altitude 1,200 meters, November, 1911.

This is probably a reduced, mossy-forest representative of the species provisionally called *Dryopteris asymmetrica;* it is not equally near to the known species with large apical leaflets—*D. simplicifolia, D. simplex, D. bakeri,* and *Haplodictyum heterophyllum.*

Near to this species, but aparently not identical, are *Elmer 10784* from Mount Apo, distributed as *D. canescens* var. *subsimplicifolia,* and *Merrill 6959,* from Canlaon Volcano, Negros.

Both are larger ferns, firmer in texture, with less setose veins, and the sporangia apparently naked; and the Canlaon plant has the pinnæ more conspicuously and uniformly contracted.

DRYOPTERIS MATUTUMENSIS Copeland sp. nov. Plate 3.

Rhizomate repente, 2–3 mm crasso, paleis parvis integris ovalis castaneis sparsis vestito; stipitibus confertis, usque ad 20 cm altis (plerumque multo brevioribus), paleis castaneis lanceolato-ovatis 2 mm longis sparsis et caducis, pilis minutis pallidis plerisque etiam deciduis, et pinnis paucis fronde (lamina) valde remotis ad auriculas abrupte reductis ornatis; fronde quam stipite longiore, vulgo 15–20 cm alta, 2.5—3 cm lata, sursum longe attenuata, in caudam integram desinente, parte superiore plerumque ultramedia pinnatifida, segmentis eiae partis contiguis, ca. 4 mm latis, obtusis vel oblique acutis, venis simplicibus; pinnis supremis paucis adnatis; inframedialibus liberis sessilibus, oblongis, apice rotundatis, crenatis vel inferioribus paucis incisolobatis, superne atroviridibus pilis minutis adspersis, inferne costa excepta glabris vel lamina punctulis ochroleucis minutis adspersa, papyraceis; venis pinnarum furcatis pinnatisve, venulis infimis rarissime anastomosantibus; pinnis infimis (auriculis exceptis) paullo diminutis, deflexis; rhachi pilis pallidis inflexis vestita; soris medialibus, regulariter ordinatis, indusiis orbiculari-reniformibus, parvis, fuscis, glabris.

MINDANAO, Mount Matutum, altitude 2,000 meters, *E. B. and H. F. Copeland*, May 1, 1917.

In aspect this fern is remarkably like that known to me as *D. philippina* (Presl) C. Chr., but is distinguished by having the full upper half of the frond, instead of a short apical portion, pinnatifid, in distinction to pinnate, and by the presence of the little auricles on the stipe. One may not be too certain of the real nature of Presl's *Physematium philippinum* without seeing Presl's type, *Cuming 251 partim.* This number is represented in several herbaria by exactly the fern described and figured by Fée as *Phegopteris nervosa,* and described by Hooker as *Nephrodium* (*Lastrea?*) *exiguum.* From recent cellections, I have this species from Los Baños, which may have been a type locality (though Hooker cites "S. Ilocos" for this number), and from northeastern Mindanao—*Bolster 327, Merrill 7328, Elmer 14026.* Presl described his plant as having sessile pinnæ. Mettenius (Phegopteris und Aspidium no. 180) keyed it out that way, but described them as "brevissime petiolata." Actually, they are short-stalked in the lower part of well-grown fronds, but sessile on small fronds. Presl carefully described them as more cut

on the acroscopic than on the basiscopic side, which is characteristic of all specimens I construe as his species, but not of *D. matutumensis*.

Dryopteris matutumensis is much closer, and possibly too close, to another fern of northeastern Mindanao, *D. urdanetensis* Copeland. This was described as having hirsute indusia; but the hairs on them are so very few, at least now, after sixteen years in the herbarium, that they would be overlooked if the description did not demand careful search. It is, however, distinguished from *D. matutumensis* by being decidedly slenderer throughout, with more densely and more persistently pubescent stipes, and fewer, less remote, and less extremely reduced basal pinnæ. The widest of some twenty fronds in hand are 17 millimeters.

DRYOPTERIS CANLAONENSIS Copeland sp. nov.

D. matutumensi affinis et similis, rhachi setis inflexis saturate purpureis dense vestita, venis segmentorum partis superioris frondis infimis et ramulis inferioribus venarum pinnarum anastomosantibus, pinnis paullo majoribus et profundius incisis, et indusiis nullis vel caducis distincta.

NEGROS, Mount Canlaon, *E. D. Merrill 6934*, April, 1910.

Like the preceding species in general aspect, and in the dissection of the frond, pinnate in the lower and pinnatifid in the upper half, and in the auricles on the stipe. Stipe about 15 centimeters tall; frond slightly longer, 4 centimeters wide, subcoriaceous in texture, dark green above and olive beneath, upper surface naked except for the appressed-pubescent costæ, beneath sparsely setose on the axes and the lamina bearing sparse minute globules; in the largest fronds, sori are borne on other, as well as on the lowest, veinlets, and these cease to be in regular rows. The historic attempts to break up this great genus, whether the resulting groups are characterized by the characters of the indusium or of the venation, would have separated these two species very widely; and yet, they could hardly be more nearly related and be separable specifically.

DRYOPTERIS AUSTRO-PHILIPPINA Copeland sp. nov.

Praecedentibus (D. urdanetensi, D. matutumensi, et D. canlaonesi) affinis; rhizomate repente, paleis castaneis 1 mm longis vestito; stipitibus dense confertis, fusco-stramineis, ad basin decidue paleaceis, alibi minute nec dense pubescentibus, vix 10 cm altis, sursum auriculis 1- vel 2-paribus 0.5–1.5 mm longis ornatis; rhachi pallide setosa; fronde 12–15 cm longa, 3 cm lata, valde

acuminata, parte supramediale pinnatifida, inframediale pinnata; segmentis partis pinnatifidae oblongis, apice rotundatis, integris, venis simplicibus infimis 1-paribus anastomosantibus, soris medialibus; pinnis sessilibus, oblongis, basi truncatis, apice rotundatis, lateribus inciso-crenatis, lobis 1.5 mm latis rotundatis, herbaceis, superne inconspicue et sparse setuliferis, inferne sparse globuliferis, pinnis infimis deflexis plerumque brevioribus; venulis plerumque 2-paribus, infimis anastomosantibus, rarius 3-paribus et medialibus in sinus conniventibus, venulis frondium fertilium omnibus plerumque soriferis, soris inframedialibus vel costularibus, multis, laminam totam deinde plus minus complentibus, indusiis nullis vel caducis.

MINDANAO, San Ramon, altitude 800 meters, *Copeland 1705* (type). Collected at the same place in 1907 and 1911; also at Camp Keithley, *Mrs. Clemens s. n.*, October, 1907. *Elmer 10204*, from the Horn of Negros, formerly determined by me as *D. canescens* var. *lobata* Christ, is probably a large form of this species, with stipes 20 centimeters tall. This plant (the type collection) was cited by Christ, Philip. Journ. Sci. 2 § C (1907) 202, as *D. philippinensis;* but it is distinct from that species in having auricles on the stipe and the upper half of the frond pinnatifid. In both of these respects it is like the preceding species. In breadth of frond and in depth of cutting of the pinnæ, it is like *D. canlaonensis;* also, its indusia are at best ephemeral, and the lowest veinlets anastomose more often than not; but the hairs on its rachis are pale, the texture is decidedly thinner, there are at most two pairs of auricles, and the upper surface of the lamina bears minute setæ, at least when young.

ATHYRIUM GYMNOCARPUM Copeland sp. nov. Plate 4.

Caudice erecto, 5 cm crasso, eodem et basibus multis applanatis stipitum truncum brevem validum efficentibus; stipitibus fasciculatis, plus minus carnosis, usque ad 25 cm altis, ad pedes negros dilatatos paleis castaneis ovatis lanceolatisve dense vestitis, sursum paleis lanceolatis pallidioribus sparsis ornatis; fronde ca. 30 cm alta, 15 cm lata, acuminata, profunde bipinnatifida, apice pinnatifida; pinnis patentibus, oppositis, subsessilibus vel supremis adnatis, infimis vex vel paullo diminutis haud deflexis, medialibus ca. 10 cm longis, acuminatis apice serratis, basitruncatis, tenuiter membranaceis, glabris, fere ad costam pinnatifidis; lobis oblongis, maximis 11 mm longis, 6 cm latis, contiguis vel infimis subremotis ala connexis, apice aequalateraliter rotundatis, obscure crenatis vel obtuse denticulatis; venulis fere

omnibus furcatis; soris subcostalaribus, elongatis, aut simplicibus, aut ad ramos ambos venularum protensis et ideo V- vel rarius Y-formibus, haud indusiatis.

MINDANAO, Mount Matutum, altitude about 1,200 meters, *E. B. and H. F. Copeland,* April 30, 1917.

Intermediate between *A. opacum* (Don) Copeland, which is bipinnate, with the basal pinnæ largest, and *A. gillespiei* Copeland, of Fiji, which has simple veinlets, and the basal pinnæ reduced and deflexed.

ATHYRIUM OREOPTERIS Copeland sp. nov. Plate 5.

Rhizomate adscendente, vero 3–5 mm crasso, basibus incrassatis stipitum caespitosorum occulto; stipitibus usque ad 30 cm altis, basibus nigris paleis laete brunneis linearibus 5 mm longis vestitis, sursum stramineis, gracilibus, glabris; fronde ca. 30 cm longa, acuminata, subbinpinnata, apice angusta pinnatifida, papyracea, glabra, inferne olivacea, rhachi nuda, facie ventrale exsculpta; pinnis subsessilibus, usque ad 8 cm longis sed plerumque brevioribus, lanceolatis, diversissime arcuatis vel rarius fere rectis et horizontalibus, valde (usque ad 5 cm inter se) remotis, infimis solummodo oppositis plerumque paullo abbreviatis, obtusis vel acutis, ad alam angustam decurrentem pinnatifidis; segmentis oblongis, apice rotundatis, basi obliquis adnatis vel majoribus acroscopice subliberis, infimis solummodo interdum liberis (et ita in pinnulas transeuntibus), minoribus argute dentatis, majoribus leviter inciso-lobatis, lobis plerisque bidentatis; venulis inferne conspicuis, nigris; soris brevibus, plerisque asplenioideis, inferioribus curvatis, indusio brunneo bullato.

LUZON, Mountain Province, Mount Pulog, altitude 2,900 meters, under rocks of open summit, *Copeland 2305,* May 13, 1909.

Faurie 566, from Mount Ari, in Formosa, altitude 2,500 meters, differs only in being larger. In that to this extent it does not fit the diagnosis based on the Luzon specimens, it may be a variety *majus.* As a Luzon plant, this is one of the northern immigrants, its affinities being only to species of farther north—as to *A. niponicum* and *A. regiscens.*

ATHYRIUM TENUIFOLIUM Copeland sp. nov.

Caudice erecto; stipite 30–50 cm alto, usque ad 5 mm crasso, basi paleis castaneis 1 cm longis anguste lanceolatis integris vestito, sursum glabrescente, ob relicta basalia palearum caducarum sparse muriculato, rhachibusque fuscis; fronde 1 m longa, subtripinnata; pinnis suprabasalibus maximis, 30–35 cm longis, 15 cm latis, alternantibus, stipitulis 1.5–2 cm longis praeditis,

acuminatis; pinnulis majoribus 8 cm longis, 25 mm latis, pedicellatis, basi cordato-truncatis, caudato-acuminatis, apice serratis, basin versus fere pinnatis, glabris, tenuiter papyraceis, atroviridibus; segmentis oblongis, obtusis, usque ad 15 mm longis, infimis 6 mm latis incisis, sequentibus 5 mm latis argute serratis; venis plerisque furcatis; soris costularibus, brevibus, plerisque ca. 1 mm (rarius usque ad 1.5 mm) longis, plerisque diplazioideis, indusio obscuro, integro.

MINDANAO, San Ramon, altitude 800 meters, *Copeland P. P. E. 198, Copeland 1493a;* Mount Apo, *Copeland 1493.*

This fern was included in *Arthyrium silvaticum* (Blume) Milde in my revision of the Philippine species of the genus, Philip. Journ. Sci. 3 § C (1908) 293, and possibly correctly. It is not *Brachysorus woodwardioides* Presl, *Athyrium basilare* Fée, a Luzon fern, distributed as *P. P. E. 82.* Its axes and palæ are not so dark, the lamina is darker, the stipe is decidedly rough, and the segments are more ample and more sharply serrate. I have no Java specimen of *Athyrium silvaticum,* which was described as with the pinnules "ad costam subtus sparsim paleaceis;" which van Alderwerelt, Malayan Ferns, p. 829, amended to "rachis and surfaces naked." The latter author says that the indusium is "ciliate or eroso-fimbriate." The most similar fern I have from Java, which I suppose to be **Athyrium muricatum** (Mettenius) Copeland comb. nov.—*Asplenium muricatum* Mettenius, Ann. Mus. Bot. Lugd.-Bat. 2 (1866) 239—has a remarkably stout and naked creeping rhizome.

ATHYRIUM CALLIPHYLLUM Copeland sp. nov. Plate 6.

Rhizomate valido, repente vel adscendente; stipitibus caespitosis, 30–35 cm altis, sulcatis, deorsum 1 cm crassis, obscuris, obique paleis castaneo-nigris angustissimis deorsum 1 cm longis plus minus rectis sursum minoribus crinitis marginibus setis minutis patentibus ornatis dense et persistente vestitis; fronde ca. 75 cm alta, ovata, profunde tripinnatifida, rhachibus setoso-paleatis, paleis in proportione crassitiei axium gradatim diminutis et remotis; pinnis infimis 20–25 cm, sequentibus fere 30 cm longis, 10 cm latis (rarius latioribus), brevi-pedicellatis, acuminatis; pinnulis infimis paullo reductis, inframedialibus maximis, 5.5–6 cm longis, 2 cm latis, acutis, brevissime pedicellatis, basi truncatis vel subcordatis, ad alam angustam coste inferne deorsum squamulosae pinnatifidis; segmentis 1 cm longis, 3–4 mm latis, spatio angustiore remotis, ala vix 0.5 mm lata connexis, obtusis, glabris, herbaceis, maximis medio ad costulas oblique

incisis, minoribus serratis; venis in lobis segmentorum majorum pinnatis, ramis utroque latere 1 vel 2; soris solitariis, simplicibus vel infimo acroscopico segmenti interdum bilaterale, e costula fere ad marginem protensis; indusio castaneo, persistente.

MINDANAO, Mount Matutum, altitude 1,800 meters, *E. B. and H. F. Copeland,* May 1, 1917.

A very distinct species, combining the foliar aspect of the group of *A. umbrosum* with axes clothed as in *A. vestitum.*

ASPLENIUM ELMERI Christ.

MINDANAO, Mount Matutum, altitude 1,800 meters, *E. B. and and H. F. Copeland,* May 1, 1917.

A common fern in Benguet. In the publication of this species, Christ mentioned a similar plant from Celebes. The Matutum specimens are typical, and, as is usual in Benguet, are bipinnate if the fronds are small, tripinnate if they are large.

LINDSAYA GRACILIS Blume (?).

MINDANAO, Mount Matutum, on *Cyathea* trunks, altitude 2,100 meters, *E. B. and H. F. Copeland,* May 1, 1917.

Lindsaya gracilis has been acredited to the Philippines in the past, but every collection known to me as responsible for such reports is the very distinct, terrestrial *L. concinna,* with clustered fronds. The Matutum specimens have tortuous, filiform, scandent rhizomes, filiform stipes 1 to 1.5 centimeters long, fronds about 10 centimeters by 8 millimeters, and pinnæ about 5 by 2.5 millimeters, most of them very shallowly 2–lobed. They conform perfectly to Blume's brief diagnosis, and reasonably well to Raciborski's more complete description. My lack of confidence in the identification is because the only specimen I have received with this name from Java is a larger and coarser fern, which I should rather call *L. adiantoides.*

CONIOGRAMME SUBCORDATA Copeland.

MINDANAO, Mount Matutum, altitude 1,950 meters, *H. F. and E. B. Copeland,* May 1, 1917.

The collection consists of a single frond, with stout, slightly scaly stipe 60 centimeters tall; lowest pinnæ 35 centimeters long; their lateral pinnules seven on a side, alternate, stalked, about 8 centimeters long, narrowed from a base about 16 millimeters wide to the very sharp tip. The pinnules of the type collection are fewer and much larger. The terminal pinnules of the Matutum plant are very long and slender. *Coniogramme squamulata* Hieronimus represents different individuals; or, perhaps, only a different individual.

MICROLEPIA TODAYENSIS Christ.

Microlepia hispidula v. A. v. R., Malayan Ferns Suppl. (1917) 233.

Copeland 1480 and *Elmer 10472*, the respective types of *M. todayensis* and *M. hispidula*, came from the same place. In reporting Elmer's collection, I held them distinct, and construed Elmer's plant as *Davallia villosa* Don. Van Alderwerelt corrected my error as to that species. With more material now in hand, I am unable to maintain any distinction between the two supposed Mindanao species. *Microlepia todayensis* is being distributed, from the base of Mount Matutum, as No. 186 of my Pteridophyta Philippinensia Exsiccata.

MICROLEPIA DONIANA Copeland nom. nov.

Davallia villosa Don, Prodromus Fl. Nepal. (1825) 10, not *Microlepia villosa* Presl.

Microlepia hirta of many authors, not of Presl.

This fern of India and Ceylon was not properly known by me when I construed one from the Philippines as identical with it. *Microlepia hirta* (Kaulfuss) Presl is known from Hawaii only.

MICROLEPIA TRAPEZIFORMIS (Roxb.) Kuhn.

A high-mountain species of northern Luzon, formerly distributed as *M. rhomboidea* (Wall.) Presl, represented by *Copeland 1891* and *Curran, Forestry Bureau 1892*, is doubtfully construed as *M. trapeziformis*. The fronds are thinly papyraceous, subtripinnate, with all axes persistently dark-hirsute, and with very hairy indusia.

PTERIS QUINQUEPARTITA Copeland sp. nov.

Species magnifica, adspectu P. tripartitae, P. radicanti affinis, apicibus non radicantibus, pinnulis multo numerosioribus et indusiis latis distincta; cuadice, teste Elmer, crassissimo, suberecto; stipitibus caespitosis, usque ad 140 cm altis, gracilibus, fusco-stramineis, ad pedes paleis paucis minutis linearibus adspersis, alibi rhachibusque validioribus mox glabrescentibus; fronde e foliolis radiatis V (rarius III) composita, quarum mediale fere 1 m longa, lateralibus late divergentibus paullo minoribus, omnibus subbipinnatis et quaque in pinnulam pinnulis lateralibus similem desinente; pinnulis sessilibus, caudato-acuminatis, usque ad 14 cm longis, 2 cm latis, pectinato-subpinnatis, costis squamulosis superne late sulcatis; segmentis contiguis et angustissime confluentibus, erecto-patentibus, apice rotundatis, intergris vel obscure crenulatis, sterilibus 3–4 mm latis, glabris, herbaceis; venis remotis, conspicuis, plerisque furcatis;

soris saepe brevibus et ad partes mediales segmentorum restrictis, nec non in fructificatione perfecta marginem fere totam occupantibus.

MINDANAO, Mount Apo, altitude 1,400 meters, *Elmer 11863* (type), *DeVore and Hoover 320, Copeland s. n.* (altitude 1,800 meters), *Williams 2456;* Mount Matutum, altitude 1,800 meters, *H. F. and E. B. Copeland.*

I have made Elmer's the type collection because it was distributed to many herbaria; but my specimen of it is the only one of the species in my possession with 3, instead of 5, primary divisions of the frond. It is cited by van Alderwerelt as *P. radicans* var. *javanica.* I have not used this varietal name as specific, because its corresponding type must be a Javan fern which I have not seen, and do not know to be identical with those from Mindanao. My field notes, made in 1903, show this fern as common in the Mount Apo rain forest, above 1,200 meters altitude. The pinnules are about 25 pairs on the middle segment, 20 on the intermediate, and 15 on the lowest, the segments radiating from a common point. *Pteris radicans* is described as having an even larger frond, but with only about half as many pinnules, and these only about 5 centimeters long, making up a frond of extremely different aspect.

HYMENOLEPIS CALLIFOLIA Christ.

MINDANAO, Mount Matutum, *Copeland P. P. E. 199.*

Previously reported only from Dutch Borneo. The Matutum specimens are thinner, longer-stalked (up to 15 centimeters), and narrower (not over 4 centimeters wide) than as described; but they are far more like the plant described by Christ than like either *H. spicata* or *H. platyrhynchos,* between which they are in some respects intermediate. The sterile segment reaches a length of 70 centimeters, the fertile 25 centimeters. The published description of the fertile segment, as vermiform, shows that it was either quite old or very dry when pressed. The rhizome is distinctive, creeping, stout, and conspicuously clothed with large, toothed, shinning, lead-colored paleæ.

To this species should probably be referred my var. *glauca* of *H. platyrhynchos,* described from Mount Apo, the fronds of which are now, after twenty years in the herbarium, brownish green, is described by Christ—no longer a glaucous blue as when fresh. The sterile segments of my specimen are short, but those of Matutum specimens are very variable. Here, too, probably belongs *Elmer 13818,* from Agusan Province, Mindanao,

conforming to Christ's description except that the greatest width of frond is only 38 millimeters, and the greatest length of spike only 10.5 centimeters.

CYCLOPHORUS LANUGINOSUS (Gies.) C. Chr.

Not uncommon in central and southern Luzon; found on Mount Matutum, in southern Mindanao, *E. B. and H. F. Copeland,* April 30, 1917; quite identical with Luzon specimens.

ELAPHOGLOSSUM ANGULATUM (Blume) Moore.

MINDANAO, Mount Matutum, altitude 1,600 meters, *E. B. and H. F. Copeland,* May 1, 1917.

Described from Java. The Matutum plant conforms to Blume's description and plate more perfectly than does McGregor's, from Benguet, given this name by van Alderwerelt, Bull. Jard. Bot. Buit., II 16 (1914) 14. The scales at the base of the stipe are appendaged exactly as figured by Blume, but those on the rhizome are almost entire when young. The paleæ of McGregor's plant are darker, longer, and more pointed.

CAMPIUM MEMBRANACEUM Copeland sp. nov. Plate 7.

C. hiteroclito affine; rhizomate 5 mm crasso, paleis castaneis lanceolato-ovatis 1.5 mm longis dense obtecto; stipitibus approximatis, frodium sterilium ca. 15 cm longis, pedes versus paleis angustis vestitis, alibi rhachique angustissime alata gracile glabrescentibus; fronde 30–35 cm longa, oblonga, pinnata deorsum subbipinnata, foliola apicale medialibus simile, oblongo-lanceolata, acuminata non flagellifera, interdum ad apicem gemmulifera, integra vel apicem versus serrulata; pinnis lateralibus plerumque 5- vel 6-paribus, medialibus ca. 10 cm longis, 2.5 cm latis, stipitulatis, integris, glabris, membranaceis, venatione laxa more C. heterocliti reticulata; pinnis infimis basiscopice auctis, plerumque cum pinnula una basiscopica et lobis confluentibus utroque latere 1 vel 2; fronde fertile conforme sed minore, pinnis 5 cm longis, 8 mm latis.

MINDANAO, Mount Matutum, *Copeland s. n.,* May, 1917.

CAMPIUM ENORME Copeland sp. nov. Plate 8.

C. gregis C. quoyani, rhizomate repente, sicco et corrugato 8 mm crasso, apicem versus paleis integris ovatis, sordide fuscis 2 mm longis deciduis vestito; stipitibus, inter se ca. 3 cm remotis, validis, erectis, frondium sterilium ca. 50 cm altis, deorsum paleis fuscis squarroso-acuminatis 3–4 mm longis et sursum similibus minoribus minus persistentibus ornatis, bisulcatis; fronde sterile

90 cm alta, pinnata apice parva pinnatifida gemmifera, pinnis grope apicem frondis gradatim reductis adnatis; pinnis liberis 20–28 paribus, infimis spatio 10 cm remotis, pedicellatis, quam sequentibus paullo minoribus; medialibus usque ad 18 cm longis, vix 3 cm latis, acuminatis, brevi-pedicellatis, basi basiscopice truncatis vel cordulato-truncatis, acroscopice latius cuneato-truncatis, ca. 1/3 ad costam oblique incisis, lobis obtusis spinescenti-denticulatis, sinubus acutis, plerisque spines occultis, herbaceis, nigro-viridibus; areolis inter costam et sinus ca. 3, inter venas primarias vulgo 5-seriatis, venulis liberis inclusis fere carentibus; fronde fertile longius stipitatis, fronde propria minore, pinnis ca. 9 cm longis, 9 mm latis, late crenatis vel subintegris inferne ubique sporangiiferis.

MINDANAO, Mount Matutum, May 1, 1917.

In fruiting condition, this is fully twice the size of common *C. quoyanum*. The other differences—such as the presence of four or five areolæ instead of two or three between adjacent main veins—are presumably correlated with the stature.

LOMAGRAMMA SUBCORIACEA Copeland ut sp. nov.

Lomagramma pteroides J. Smith var. *subcoriacea* COPELAND, Philip. Journ. Sci. 8 § C. (1908) 32.

I have now ample and thoroughly mature material of this plant, collected on Mount Matutum, and am satisfied that, as was suggested when it was described as a variety, it will better be regarded as specifically distinct. The peculiarities of firm texture, reddish color, and salient veins are constant, as are also the cordate-truncate bases of the sterile pinnæ. The fertile pinnæ are either obtusely hastate-lobed, or auriculate at the base. The sterile fronds may reach a length of a meter; the fertile are not quite so large. The rachis is densely and rather persistently scaly; the lamina minutely and less persistently so.

POLYPODIUM SPONGIOSUM Copeland sp. nov. Plate 9.

P. negrosensi affine; rhizomate breve, pilis fuscis ovato-lanceolatis minusquam 1 mm longis minute pallide ciliatis vestito, basibus radicum et stipitum exarticulatorum obtecto; stipitibus 5–10 mm longis, pilis vinicoloribus 1 mm longis horizontalibus dense vestitis; fronde lineare pendente, maxima visa 16 cm longa, 18 mm lata, obtusa, deorsum gradatim angustata, ad alam rhacheos pinnatifida; rhachi immersa, setosa, alis inclusis ca. 3 mm lata; segmentis apud rhachin 4–5 mm latis, ibidem subcontiguis et obliquis (acroscopice dilatatis), deinde usque ad apices rotundatas angustatis, integris, carnois (in siccitate col-

lapsis), minute purpureo-ciliatis et alibi sparsius pilosulis; costulis sinuatis; venis simplicibus vel infima acroscopica rarius furcata, immersis, ad marginem haud appropinquantibus; soris paucis, apices prope segmentorum, inter costulam et marginem medialibus, pilis densioribus cricumdatis, vix vel haud immersis. A P. negrosense, frondibus minus abrupte angustatis, segmentis remotioribus acroscopice dilatatis, et soris praestantius superficialibus distinctum.

MINDANAO, San Ramon, *Copeland s. n.* 1920, altitude 1,200 meters. Epiphytic on mossy trunks.

Distinguished from *P. khasayanum* and *P. barathrophyllum* by more spongy texture, hairier stipes, superficial sori, and the segments dilated on the upper side at the base.

POLYPODIUM MILLEFOLIUM Blume.

MINDANAO, Mount Matutum, altitude 2,100 meters.

Already known from Mount Malindang in Mindanao and Mount Kinabalu in Borneo, as well as from Java and Sumatra. The citation in Christensen's Index, Flora Javae Plate 78 A, agrees with Blume's text, p. 190; however, it should be Plate 88 B.

POLYPODIUM SUMATRANUM Baker.

MINDANAO, Mount Matutum, altitude 1,950 meters.

Already known from Mount Apo (as *P. pleiosoroides* Copeland), from Mount Kinabalu, and from Java and Sumatra.

Polypodium serraeforme Brause (not of J. Smith) is probably a small form of this species, our specimen of *Schlechter 18142* being altogether like some of the smaller ones from Matutum. The receptacles are mostly elongate (though the sori appear round), and superficial. The larger Matutum specimens have laminæ nearly 25 centimeters long, on stipes up to 6 centimeters long. The margin varies, from entire, through broadly crenate, to irregularly lobed.

POLYPODIUM BULBOTRICHUM Copeland sp. nov.

Grammitis, rhizomatis, brevi-repente vel suberecto, paleis ferrugineis ovatis obtusis vel apiculatis 1.5–2 mm longis vestito; stipitibus subfasciculatis, non vel vestigialiter articulatis, usque ad 6 (plerisque 3–4) cm longis, gracilibus, pilis castaneis debilibus et fragilibus usque ad 2 mm longis basibus plerumque inflatis interdum praestantim mammiformibus obsitis, deinde, pilis abrasis, plus minus horridulis; fronde lineare, usque ad 16 (plerumque ca. 10) cm longa, utrinque angustata, in herbario fusca et subcoriacea, sparse castaneo-setosa, nisi prope soros

glabrescente, decidue ciliata, in parte superiore cum pilis aliquot secus marginem sursumplexis, costa nigrescente; venis inconspicuis, saepe bis furcatis; soris subcostalibus, ad venulas infimas acroscopicas, setis protectis, receptaculo paullo elongato.

LUZON, Mountain Province, Mount Pulog, altitude 2,650 meters, *Copeland P. P. E. 136* (type), epiphytic in mossy forest, May 12, 1909, *Merrill 6376;* Pauai, altitude 2,100 meters, *Copeland 1949,* November, 1905; Mount Bulusan, altitude 2,650 meters *Copeland s. n.,* May, 1913.

This species has been distributed as *P. congenerum* and *P. caespitosum,* from both of which it is distinguished by the long hairs on the stipe, their stipes being densely short-pubescent. From these and other species it is usually easily distinguished by the swollen bases of the hairs on the stipe, and the hairs appressed to the margin of the upper part of the frond. Both of these features are variable; the appressed hairs are sometimes few, and may be lost; and the swollen bases, usually very conspicuous, are hardly evident on some stipes. *Polypodium fasciculatum* has long, weak hairs on the stipe, but they are pale; and its paleæ are narrow.

POLYPODIUM HEANOPHYLLUM Copeland sp. nov.

Grammitis, P. setigero affinis eodemque quondam confusa, paleis parvis occultis, frondibus tenuioribus, stipitibus densius hirsutis, laminis minus setigeris distincta, epiphytica; rhizomate ubique radicibus basibusque hirsutissimis stipitum profunde occulto, paleis brunneis 1–2 mm longis vestito; stipitibus percaespitosis, 2–8 cm longis, gracilibus, pilis castaneis horizontalibus 2–4 mm longis dense hirsutis; fronde pendente, usque ad 35 cm longa et 17 mm lata lateribus parallelibus, obtusa, basi acuta, pilis 2–3 mm longis ciliata, faciebus sparsim pilosis, fusca, siccatate membranacea; venatione luce reflecta occulta, luce permissa praestante, venis plerisque 2– vel 3–furcatis, venulis late divergentibus deinde curvatis et marginem versus currentibus; soris ad venulas infimas acroscopicas basalibus, subcostalibus, sporangiis setuliferis.

MINDANAO, Mount Matutum, altitude 2,000 meters, *Copeland, P. P. E. 158* (type); Mount Apo, *Copeland 1521, Elmer 11440,* distributed as *P. setigerum.*

This species is common at about 1,800 meters altitude on Mount Apo, where it has been collected repeatedly, and easily confused with *P. setigerum.* With ample material of both, of

my own collection and in hand together, the thinness of the Mindanao plant is at once conspicuous. With comparison invited by this difference, that of the paleæ is still more striking. These are 4 to 5 millimeters long on *P. sentigerum,* and very conspicuous, while on *P. heanophyllum* they are less than half as large, and visible at all only after the removal of a mass of stipe-bases. The sori are less strictly costal, and the difference in hairiness has already been noted. In texture and paleæ, *P. heanophyllum* differs alike from *P. setigerum* and *P. hookeri.* In both *P. setigerum* and *P. heanophyllum,* there is an occasional irregular anastomosis of the veinlets.

PROSAPTIA URCEOLARE (Hayata) Copeland comb. nov.

Polypodium urceolare HAYATA, Icones Plant. Formosanarum 5 (1915) 324.

Caudice suberecto, paleis fusco-griseis castaneo-ciliatis 4–7 mm longis e basi 1 mm lata usque ad apicem sensim angustatis vestito; stipitubus caespitosis, vestigialiter ad rhizoma articulatis, ca. 2 cm longis, pilosis, pilis 1.5 mm longis atrocastaneis; fronde usque ad 23 cm longa, lineare vel lineari-lanceolata, utrinque sensim angustata, basi in alam brevem et angustatam ad stipitem decurrentem descrescenta, fere ad costam pinnatifida, coriacea, ubique sed haud dense (inferne brevius) pilosa; costa valida sed immersa; segmentis modo remotis, majoribus ca. 1 cm longis et 4 mm latis, obtusis, margine sterile integra, fertile crenata; soris magnis, paucis, partes distales sed apices ipsas rarissime segmentorum occupantibus, utraque facie laminae perconspicuis, marginalibus sed inferne potius quam lateraliter apertis, ore valde elevato in maturitate fere orbiculare circumdatis.

LUZON, Benguet, Pauai, altitude 2,350 meters, *Copeland, P. P. E. 149,* May 9, 1909; also Mount Bulusan (prope Pauai), altitude 2,500 meters, *Copeland, s. n.,* May, 1913.

The specimens fit Hayata's description and figures perfectly except as to the pubescence of the paleæ; as to this, his figure is perhaps not accurate.

This species is a *Prosaptia,* rather than a *Polypodium,* if the usual generic boundary is to be maintained, in spite of the fact that its sori open obliquely toward the nether surface and the apex of the segments and the margin, rather than distinctively laterally. In this respect, it is like *P. alata* and its near relatives, rather than like *P. contigua.* In the absence of any conspicuous wing at the base of the frond, it is like *P. contigua* and unlike

P. alata. The sterile apex of the segments is a distinctive character, probably associated with the extreme prominence of the sori. Except when the very abundant sporangia conceal it, the rim of the sorus is fully as conspicuous as in *P. celebicum,* with which *P. craterisorum* Harr. is completely synonymous. *Prosaptia bolsteri* is probably a small *P. alata*—small because imperfectly developed, rather than fixed as even a local variety. As to the near affinity of *Prosaptia* and *Cryptosorus,* Hayata, l. c., lays down in more detail facts to which I had already (as had J. Smith and others before me) paid attention. It does not necessarily follow from these facts that *Polypodium* is the proper name of this fern. The selection of boundary lines between genera is usually facilitated for us by our not having before us the steps through which daughter groups have evolved from their parents. However, we would not abandon our practice of recognizing genera if our knowledge of all such steps were perfect, and convenience may provide ample justification for our maintaining as distinct genera the comparatively few markedly peculiar derived groups which we can connect with their parents by an approximately continuous series of living species. Some of us have observed such an artificial boundary, somewhere between *Polypodium obliquatum* and *Prosaptia alata, Prosaptia contigua* representing the "type" reached by evolution in its direction. My present judgment is that Christensen, Mittheilungen Inst. Allegen. Bot. Hamburg 7 (1928) 158, has proposed a better place for this line, nearer the parent group, so as to include (in *Prosaptia*) *Polypodium obliquatum* and its immediate relatives. The same author is absolutely right, Dansk. Bot. Arkiv. 5, No. 22 (1928), in the opinion that the type of *Polypodium* is far more nearly related to a group often called (whether or not properly) *Goniophlebium* than to the very large group of small tropical epiphytes sometimes distinguished as *Ctenopteris.* Our present enormous genus *Polypodium* will be broken up. When this is done, with due regard to phylogeny, convenience, and any rules of nomenclature, the alternative to recognizing *Prosaptia* as a genus, with species counted by the dozen, will be its extension to include several hundred species.

VITTARIA STENOPHYLLA Copeland sp. nov.

Taenioupsis, rhizomate repente, paleis castaneis griseo-iridescentibus 5 mm longis e basi 0.5 mm lata ad apicem filiformem sensim attenuatis; frondibus densissime caespitosis, usque ad 15 cm longis, 1.5 mm latis, apice valde acuminatis sterilibus, basi

ad stipites 0–3 cm longus sensim angustatis, inconspicue costatis; soris intramarginalbus, leviter immersis, utroque latere costae partem majorem longitudinis occupantibus, paraphysibus turbinatis oleaginis.

LUZON, Benguet, Mount Santo Tomas, altitude 2,300 meters, *Copeland P. P. E. 122* (type), May 1909, epiphytic on *Cyathea* trunks in mossy forest; also, in Lepanto, near Bagnen, *Copeland 1928*, November, 1905.

Similar to *V. angustifolia* Blume, from which it is most evidently distinguishable by smaller and darker paleæ. *Vittaria alternans* is notably slenderer. The very slender and sharp sterile apices, commonly about 2 centimeters long, are a conspicuous character of *V. stenophylla.* At the base, the fronds merge insensibly into stipes about 0.25 millimeter wide but without definite length.

ILLUSTRATIONS

[All plates are from photographs by W. C. Matthews. The scale is indicated by the centimeter scale on each photograph. The enlargement of detail drawings is proportional; that is, they are drawn magnified as stated on the drawings and then photographed down with the rest of the plate.]

PLATE 1. *Gleichenia peltophora* Copeland. Type.
2. *Dryopteris elmerorum Copeland.* Type.
3. *Dryopteris matutumenis* Copeland. Type.
4. *Athyrium gymnocarpum* Copeland. Type.
5. *Athyrium oreopteris* Copeland. Type.
6. *Athyrium calliphyllum* Copeland. Type.
7. *Campium membranaceum* Copeland. Type.
8. *Campium enorme* Copeland. Type.
9. *Polypodium spongiosum* Copeland. Type.

PLATE 1. GLEICHENIA PELTOPHORA COPELAND. TYPE.

PLATE 2. DRYOPTERIS ELMERORUM COPELAND. TYPE.

PLATE 3. DRYOPTERIS MATUTUMENSIS COPELAND. TYPE.

PLATE 4. ATHYRIUM GYMNOCARPUM COPELAND. TYPE.

PLATE 5. ATHYRIUM OREOPTERIS COPELAND. TYPE.

PLATE 6. ATHYRIUM CALLIFOLIUM COPELAND. TYPE.

PLATE 7. CAMPIUM MEMBRANACEUM COPELAND. TYPE.

PLATE 8. CAMPIUM ENORME COPELAND. TYPE.

PLATE 9. POLYPODIUM SPONGIOSUM COPELAND. TYPE.

NEW OR LITTLE-KNOWN TIPULIDÆ FROM EASTERN ASIA (DIPTERA), IV [1]

By Charles P. Alexander

Of Amherst, Massachusetts

THREE PLATES

The crane flies discussed at this time are from various parts of eastern and southern Asia and were received from the following entomolgists and collectors: China, Messrs. A. P. Jacot, E. Suenson, and T. Yokoyama; Japan, Messrs. Teiso Esaki, C. Harukawa, S. Kuwayama, Jiro Machida, Akio Nohira, S. Sakaguchi, and E. Suenson; Formosa, Messrs. S. T. Issiki and K. Takeuchi; Philippines, Messrs. Duyag, McGregor, and Rivera; and India, Mr. C. F. C. Beeson and the authorities of the Indian Museum. I wish to express my deepest thanks to all of the above-named gentlemen for the opportunity of studying the great collections of crane flies upon which the following descriptions are based. Except where stated to the contrary, the types of the novelties are preserved in my collection.

The crane-fly fauna of the Oriental Region is tremendously large and varied, more especially so on the slopes and summits of the higher mountains where a characteristic Palæarctic element is found. There can be little question that this region, with its abundant isolated mountain ranges, major islands, and archipelagoes, separated for past ages and having had an abundance of time for the formation of species, will be found to support a greater number of species of Tipulidæ than any other region of the World.

TIPULINÆ

TIPULINI

BRITHURA SANCTA sp. nov.

General coloration dark clove-brown, the præscutum with three paler reddish brown stripes; pleura light brown with two narrower dark brown longitudinal stripes; femora yellowish brown, the tips narrowly blackened, preceded by a clearer yellow sub-

[1] Contribution from the Department of Entomology, Massachusetts Agricultural College.

terminal ring; wings with Sc_1 present; Rs subequal to R_3, the latter angulated and short-spurred near outer end; male hypopygium large, the sternal region only moderately produced.

Male.—Length, excluding head, about 26 millimeters; wing, 23 by 6. Head broken.

Pronotum yellow, the posterior notum with two approximated median tubercles that are dark brown, the anterior notum darkened laterally. Mesonotal præscutum dark clove-brown with three nearly confluent reddish brown stripes, the dark ground color restricted to the humeral and lateral regions; median stripe broad; scutum chiefly reddish brown; scutellum dark reddish brown, more blackened medially, the parascutella black; postnotal mediotergite dark brown, the posterior portion with an obscure yellow triangle. Pleura light brown with two narrow darker brown longitudinal stripes, the more dorsal lying just beneath the dorsopleural membrane, including the propleura; ventral stripe including the fore coxæ, continued across the sternopleurite to the metapleura; pleurotergite elevated, the anterior face with an appressed yellow pubescence. Halteres light reddish brown, the base of each knob darker. Legs with the coxæ dark brown; trochanters paler, especially the fore trochanters; femora yellowish brown, the base and a subapical ring clearer yellow, the tip narrowly blackened; tibiæ brown, the base yellow; tarsi brown. Wings (Plate 1, fig. 1) as in the genus; costal region opposite the stigma dilated but not broken; ground color yellow, with a sparse dark pattern, including the bases of cells R and M; origin of Rs; a large area extending from the stigma across the cord; outer ends of all outer cells from R_3 to 2d A inclusive infumed, most of them inclosing small marginal yellow areas; medial veins beyond the cord narrowly bordered by yellow, which in turn has a dusky margin, darker than the centers of the cells; a conspicuous darkened area on either side of vein 1st A at near midlength; veins yellow, the costal vein more reddish brown. Venation: Sc_1 present; Rs strongly arcuated, subequal to R_3, the latter angulated and short-spurred just before apex; cell 1st M_2 higher than long.

Abdominal tergites brownish black; hypopygium conspicuously reddish; sternites reddish brown. Male hypopygium (Plate 2, fig. 19) relatively large but ninth sternite, 9*s*, not greatly developed, as is the case in *B. crassa* Edwards. Ninth tergite 9*t*, narrowed outwardly, the caudal margin with a deep U-shaped emargination that is fringed with conspicuous erect yellow setæ, the lateral lobes thus formed relatively conspicuous. Basistyle,

b, produced, the apex flattened, provided with long yellow setæ. Dististyle, *d*, shiny reddish brown, very large and complex in structure. Ninth sternite, 9*s*, produced into a median tubercle of moderate size.

Habitat.—China (Chi li).

Holotype, male, Ton Che ssu, a temple in hills west of Peking, August 27, 1921 (*A. P. Jacot*).

Brithura sancta differs from *B. nymphica* Alexander, which seems to be its nearest relative, in the details of coloration and venation, especially the retention of Sc_1 and the arrangement of veins in the radial field. The venation of *B. conifrons* Edwards, the genotype, is shown for comparison (Plate 1, fig. 2).

TIPULA SUBFUTILIS sp. nov.

Allied to *T. futilis* Alexander; antennæ with the basal segments of the flagellum bicolorous; wings with a complete white crossband beyond the cord; distal end of R_{1+2} atrophied; male hypopygium with the lateral lobes of the ninth tergite very low and obtuse, the caudal margin notched, with two small submedian ridges; gonapophyses blackened, simply bispinous.

Male.—Length, about 13 millimeters; wing, 16 by 3.7.

Described from an alcoholic specimen.

Frontal prolongation of head relatively long, brownish yellow; palpi pale. Antennæ of moderate length, if bent backward extending to shortly beyond the base of the abdomen; basal segment yellow; second scapal segment brown; first flagellar segment yellow; succeeding segments brown, the distal end yellow, the amount of the latter decreasing on the outer segments, on the second flagellar including only the distal fourth; beyond the fifth flagellar, the segments are entirely brown; terminal flagellar segment very small, oval. Head brownish gray; vertical tubercle low and obtuse, entire.

Mesonotal præscutum pale brown, with three paler, more brownish yellow stripes that are ill-defined against this background; scutellum and postnotum yellowish brown, with a delicate brown median vitta. Pleura uniformly brownish yellow, possibly pruinose in dry specimens. Halteres chiefly pale. Legs with the femora brownish yellow, clearer basally, darker at tips; tibiæ and tarsi passing into dark brown. Wings relatively long and narrow, as shown by the measurements; pattern almost as in *T. futilis*, the ground color brownish, variegated with whitish subhyaline, this latter including a complete crossband beyond the cord; smaller pale areas in cell R, before the stigma; near outer end of cell M; at outer end of cells Cu and 1st A, crossing

the latter vein; and at midlength of cell 1st A, not touching the veins; darker areas than the ground color at origin of Rs, anterior cord and as a conspicuous seam along the distal half of Cu_1. Venation: R_{1+2} pale at base, scarcely visible, the outer end entirely atrophied; R_2 short, perpendicular.

Abdominal tergites obscure yellow with a narrow but conspicuous median brown line that is nearly continuous; sternites more uniformly yellow. Male hypopygium (Plate 2, fig. 20) with the ninth tergite (Plate 2, fig. 21) extensive, gradually narrowed outwardly, the caudal margin with a very shallow emargination, the lateral lobes thus formed very low and obtuse; a very small rounded tooth on either side of the median line, these produced back onto the dorsal surface of the tergite as short ridges that inclose a narrow linear furrow. Outer dististyle widely expanded outwardly. Gonapophyses, *g*, appearing as heavily blackened structures that lie on either side of the ædeagus, each apophysis bispinous, the more dorsal spine a little longer.

Habitat.—Japan (Kiushiu).

Holotype, alcoholic male, Unzen Park, Hizen, May, 1926 (*E. Suenson*), received through Doctor Crampton.

Tipula futilis Alexander (Japan) differs from the present species in the details of structure of the male hypopygium. In *T. futilis,* the caudal margin of the ninth tergite (Plate 2, fig. 22) is more deeply and evidently notched, the margin heavily blackened, the lateral lobes more conspicuous; the base of the notch bears a small black median tooth, in addition to two smaller and blunter sublateral knobs; dorsal surface not evidently ridged and furrowed as in *subfutilis.* Outer dististyle (Plate 2, fig. 23) quite as in *T. subfutilis.* Inner dististyle, *id,* with the ventral margin produced into a stout lobe that ends in a nearly terminal black spine. Gonapophyses, *g*, with the dorsal arm bifid, the ventral arm longer and slenderer than in *T. subfutilis.*

TIPULA YUSOUOIDES sp. nov.

Male.—Length, about 14 millimeters; wing, 17.

Female.—Length, about 20 millimeters; wing, 19.

Described from alcoholic specimens.

Closely allied and generally similar to *T. yusou* Alexander (Japan), differing chiefly in the structure of the male hypopygium.

Male hypopygium (Plate 2, fig. 24) with the caudal margin of the ninth tergite arched and heavily blackened, as in *T. yusou,*

the dentation of the margin quite different, the most ventral tooth on either side being much larger and produced into an acute spine. Outer dististyle smaller, more dilated before apex. Inner dististyle, *id*, with the blade much smaller, the bilobed apex heavily blackened and relatively small. Eighth sternite, 8*s*, with the caudal lobe longer than broad, clothed with abundant long golden setæ.

Habitat.—Japan (Kiushiu).

Holotype, male, Unzen Park, Hizen, May, 1926 (*E. Suenson*). Allotopotype, female.

In *Tipula yusou* Alexander [2] the caudal margin of the tergite is highly arched, narrowly blackened, with numerous small teeth and lobules, none of which is acute. Outer dististyle elongate, gradually widened outwardly. Inner dististyle large, the blades conspicuous. Eighth sternite with the caudal lobe transverse, the setæ chiefly marginal.

TIPULA SUBYUSOU sp. nov.

Male.—Length, about 16 millimeters; wing, 18.

Closely allied to *T. yusou* Alexander (Japan), differing especially in the structure of the male hypopygium.

Ninth tergite with the caudal margin narrowly darkened or blackened but without distinct denticles. Outer dististyle nearly as in *T. yusouoides*, being rather conspicuously dilated just beyond midlength. Inner dististyle with the outer marginal lobe intensely blackened, obtusely rounded, the caudolateral margin bearing a pale lateral flange. Eighth sternite with the caudal lobe transverse, its margin with a dense brush of long golden setæ. Gonapophyses (Plate 2, fig. 25) trifid, as in *T. yusou*, but the arms much longer and slenderer, arising from a long, heavily blackened base, the arms gently curved and slightly decurved. In *T. yusou* (Plate 2, fig. 26), the gonapophyses are paler and nearly straight, the longer median spine subtended by the lateral spines.

Habitat.—Japan (Honshiu).

Holotype, male, Mount Takao, altitude 1,000 to 2,000 feet, May 7, 1922 (*Teiso Esaki*). Paratype, male, Nakano, Tokyo, May 1, 1922 (*Teiso Esaki*).

TIPULA RANTAICOLA sp. nov.

General coloration ocherous yellow, the præscutum with ill-defined darker stripes; antennæ bicolorous; wings grayish brown,

[2] Canadian Entomologist 46 (1914) 240–241, pl. 19, fig. 1.

certain of the veins seamed with darker; cell 1st M_2 very small; male hypopygium with the median region of the tergite produced into a decurved setiferous lobe.

Male.—Length, about 9 to 10 millimeters; wing, 9 to 10.

Female.—Length, about 11 millimeters; wing, 11.

Frontal prolongation of head brownish yellow; palpi dark brown. Antennæ with the scape yellow; flagellum weakly to strongly bicolorous, the basal enlargement of each segment brownish black, the remainder brownish yellow to yellow; antennæ (male) relatively elongate, if bent backward extending to some distance beyond base of abdomen; antennæ (female) shorter, distinctly bicolorous. Head brownish gray, clearer gray in front; a narrow dusky median line on anterior vertex.

Mesonotal præscutum ocherous yellow, the three usual stripes only a trifle darker, the median stripe split by a capillary, slightly darker vitta; scutal lobes extensively darkened; scutellum and postnotum brown. Pleura brown. Halteres yellow, the knobs infuscated, their apices pale to distinctly yellow. Legs with the coxæ and trochanters yellow; femora yellow, passing into dark brown; tibiæ and tarsi dark brown. Wings (Plate 1, fig. 3) with a grayish brown suffusion, the base and costal region more yellowish; cell C a trifle infumed; stigma conspicuous, dark brown; outer end of cell R_2 darkened; conspicuous brown seams on Cu, m-cu, and more narrowly on most other longitudinal veins; extensive whitish areas before and beyond the stigma and across cell 1st M_2; veins dark brown, the obliterative areas whitish, the veins in the yellowish areas more flavous. Macrotrichia of veins very long and abundant. Venation: Cell 1st M_2 very small, diamond-shaped to pentagonal.

Abdominal tergites obscure yellow, the lateral and caudal margins of the segments blackened, the amount increasing on the outer segments; sternites yellow, the caudal margins of the segments a little darkened; eighth sternite blackened; hypopygium chiefly pale. Male hypopygium small, the median region of the tergite produced into a conspicuous decurved lobe, the sides of which are densely clothed with conspicuous yellow setæ. Inner dististyle large, jutting caudad as large, compressed to slightly tumid lobes, the apex of each with a small group of black spinous setæ, this lobe much larger than the flattened outer dististyle. Eighth sternite unarmed.

Habitat.—Formosa.

Holotype, male, Rantaizan, altitude 7,000 feet, June 2, 1927 (*S. T. Issiki*). Allotopotype, female. Paratopotypes, 4 males.

Tipula rantaicola bears a marked resemblance to *T. microcellula* Alexander (Plate 1, fig. 4) in the general appearance and very small cell 1st M_2, differing especially in the details of coloration, wing venation, and the structure of the male hypopygium, especially the ninth tergite which here bears a setiferous median lobe.

NESOPEZA RANTAIZANA sp. nov.

General coloration ocherous, the mesonotal præscutum with a median darker line; antennæ (male) relatively long; legs brown, the tibiæ and tarsi extensively white; wings nearly hyaline, the stigma brown; free tip of Sc_2 nearly atrophied, indicated only by a pale line; basal section of R_{4+5} and r-m pale, without macrotrichia, in transverse alignment; forks of medial field relatively shallow, male hypopygium with the tergite produced laterad into slender blackened rods, the median area of the caudal region further produced into a decurved point.

Male.—Length, about 8 millimeters; wing, 10.

Rostrum testaceous yellow; palpi pale brown. Antennæ with the scapal segments yellow, the flagellum dark brown; antennæ 12-segmented, the terminal segment small; flagellar segments with dense short setæ and longer unilaterally arranged black verticils that are conspicuous but scarcely one-half the length of the segment. Head ocherous yellow.

Thorax almost uniformly ocherous, the præscutum with a median darker line; pleura more testaceous. Halteres very long and slender, pale brown, the knobs darker. Legs with the coxæ and trochanters yellowish testaceous; femora brown; posterior tibiæ dusky, the extreme tips white; tarsi dusky, the tips paling to white; on the other legs the amount of white on the tibiæ and tarsi appears to be more extensive. Wings (Plate 1, fig. 5) relatively broad, nearly hyaline, the oval stigma brown; veins brown, unusually slender, with long conspicuous macrotrichia. Macrotrichia on the distal third of vein M, distal half of basal section of Cu_1, and outer ends of both anal veins. Venation: Sc_2 ending opposite four-fifths the length of Rs; free tip of Sc_2 atrophied or barely visible; basal section of R_{4+5} and r-m pale, without macrotrichia, in transverse alignment; forks of medial veins relatively shallow; m-cu subtransverse; cell 2d A narrow.

Abdomen yellowish brown, darker laterally. Male hypopygium with the lateral margins of the tergal region produced caudad and slightly mesad into slender blackened arms, their

tips microscopically spiculose; median region of tergite with a broad-based acute median point that is directed ventrad, the margin of the tergite dorsad of this with a fringe of long erect setæ; tergite pale except for the blackened lateral and caudal margins. Outer dististyle relatively short and inconspicuous, cylindrical, the apex truncate. Inner dististyle deeply bifid.

Habitat.—Formosa.

Holotype, male, slightly teneral, Rantaizan, altitude, 7,000 feet, June 2, 1927 (*S. T. Issiki*).

NESOPEZA IDIOPHALLUS sp. nov.

General coloration dark brown; antennæ with the scapal segments yellow, the flagellum dark brown; front and anterior vertex conspicuously yellow; mesonotum chiefly dark brown, median area of the præscutum and scutum paler; pleura pale brownish yellow, the anepisternum and sternopleurite conspicuously dark brown, legs dark brown, the tarsi extensively snowy white; male hypopygium with the ædeagus conspicuous, subtended on either side by a flattened spinous arm.

Male.—Length, about 10 millimeters; wing, 11.5.

Female.—Length, about 15 millimeters; wing, 13.

Frontal prolongation of head brown, entirely without nasus; palpi dark brown. Antennæ (male) of moderate length, if bent backward extending about to the base of the abdomen; scapal segments pale yellow, the flagellum dark brown; flagellar segments elongate-cylindrical, the basal enlargements of the segments inconspicuous, the verticils scattered, shorter than the segments. Front and anterior vertex pale yellow; remainder of head dark brown.

Pronotum brown, the posterior notum more yellowish. Mesonotal præscutum dark brown, the median area somewhat paler; scutum dark brown, the median region paler; posterior sclerites of mesonotum testaceous brown. Pleura pale brownish yellow, with a broad transverse dark brown girdle that includes the anepisternum and sternopleurite; meron similarly darkened. Halteres pale, the knobs dark brown. Legs with the coxæ yellow, a little darkened at base; trochanters yellow; femora dark brown, their bases paler; tibiæ and tarsi dark brown, the distal fifth of the basitarsi and remaining tarsal segments snowy white. Wings with a strong brownish suffusion, the oval stigma darker brown; ill-delimited dark clouds on anterior cord and m-cu; whitish obliterative areas before and beyond the stigma and across the fork of M. Venation: Rs of moderate length, about

one-half longer than R_{2+3}; forks of medial cells relatively shallow; m-cu about one-third its length before the fork of M.

Abdominal tergites brown, the incisures, including the broad base and narrower apex of each segment, more blackened; subterminal segments black; hypopygium obscure yellow, including the conspicuous ædeagus. Ædeagus (Plate 2, fig. 27) very conspicuous, jutting caudad and ventrad from the genital chamber, long, pale yellow, at near midlength subtended on either side by a flattened yellow blade that is bispinous at and near apex. Ovipositor with the tergal valves relatively short and wide, their tips obtuse.

Habitat.—China (Che-kiang).

Holotype, male, hills south of Ning-po, May 1, 1925 (*E. Suenson*). Allotopotype, female.

OROPEZA SATSUMA Alexander.

Oropeza satsuma ALEXANDER, Journ. New York Ent. Soc. 26 (1918) 67–68.

The holotype was from Kioto, Japan, July, 1916 (*Akio Nohira*). The male hypopygium of the type was not discussed and may be briefly described as follows: Male hypopygium (Plate 2, fig. 28) with the ventrolateral angles of the tergite produced ventrad, caudad, and mesad into a curled flattened ribbonlike plate; mesal region of sternite produced strongly ventrad. Outer dististyle, *od*, pale, of moderate length only, narrowed gradually to the obtuse apex, provided with abundant long pale setæ. Ninth tergite (Plate 2, fig. 29) entirely pale, the caudal margin subtransverse, crenate, with a very low and shallow median notch and still smaller, more circular, sublateral incisions; the major incisions that separate the caudal margin from the flattened ventrolateral arms are even deeper.

OROPEZA BISPINULA sp. nov.

General coloration dark brown, the præscutum with three still darker stripes; tibiæ and tarsi brown; wings with a pale brown suffusion, the stigma dark brown, preceded and followed by conspicuous pale yellow areas; abdomen beyond base deepening to black; male hypopygium with the caudal margin of the ninth tergite with two black, needlelike points.

Male.—Lenght, about 10.5 millimeters; wing, 10.5

Rostrum and palpi dark brown. Antennæ with the scapal segments yellow, the flagellum dark brown; flagellar segments cylindrical, the outer segments gradually shortened; verticils

a little shorter than the segments; antennæ of moderate length, if bent backward extending about to the root of the halteres. Head light brown.

Mesonotal præscutum dark brown, subnitidous, with three brownish black stripes; scutum, scutellum, and postnotum uniformly dark brown. Pleura dark liver brown, the dorsopleural membrane pale. Halteres pale, the knobs brown. Legs with the coxæ concolorous with the pleura; trochanters yellow; femora dark brown, the tips broadly more yellowish; tibiæ and tarsi brown. Wings (Plate 1, fig. 6) with a pale brown suffusion, the base and costal region a little more saturated; stigma oval, dark brown; conspicuous pale yellow antestigmal and poststigmal areas, the latter including more than the basal half of cell Sc_2; veins dark. Venation: Rs transverse, opposite Sc_2; R_1 and R_2 in nearly transverse alignment; R_{1+2} entirely atrophied.

Abdomen with the basal tergites obscure brownish yellow, beyond the second segment reddish brown, gradually deepening to black; sternites beyond the basal segment obscure yellow with narrow black cross lines near base and at margins; outer sternites uniformly darkened; male hypopygium with the inner dististyle, *id*, yellowish, the remainder chiefly dark. Male hypopygium (Plate 2, fig. 30) with the caudal margin of the ninth tergite, 9*t*, nearly transverse, the median area blackened, chitinized, produced into two slender, needlelike points, one on either side of the median line (Plate 2, fig. 31).

Habitat.—Japan (Honshiu).

Holotype, male, Lake Ozenuma, on boundary between Iwashirono-kuni and Kotsuke-no-kuni, altitude 5,410 feet, July 25, 1923 (*Teiso Esaki*).

OROPEZA SAUTERI Riedel.

Oropeza sauteri RIEDEL, Archiv für Naturgeschichte 82 (1917) 114–115.

Riedel's types, both sexes, were from Okaseki, Taihoku District, Formosa, collected in June, 1914, by Sauter. I have seen additional males and females from Taihoku, taken April 20, 1922, by K. Takeuchi.

These latter specimens agree very closely with Riedel's description except that the incisures of the abdomen are not darkened but the narrow transverse dark marking of each segment lies at or before midlength of the segment, the base and apex being broadly yellowish. The sternities are extensively brown at the base and very narrowly so at the apex, with a conspicuous

yellowish ring before the apex; subterminal segments more uniformly darkened; hypopygium small, chiefly obscure yellow. Male hypopygium with the median notch of the tergite small, U-shaped with no distinct notches or incisions laterad of this; ventrolateral arms of tergite terminating in large oval heads.

LIMONIINÆ

LIMONIINI

LIMONIA (LIMONIA) RANTAIENSIS sp. nov.

Mesothorax shiny black; halteres yellow; legs black, the broad femoral bases, a subterminal femoral ring, and the narrow bases of the tibiæ yellow; wings yellowish, the veins seamed with brown; Sc short; R_{1+2} elongate.

Female.—Length, about 9 millimeters; wing, 9.3.

Rostrum and palpi black. Antennæ with the scape black, the basal flagellar segments black with their tips somewhat more brownish; flagellar segments oval, the verticils considerably longer than the segments. Head brownish black, not nitidous; anterior vertex a little wider than the first scapal segment.

Pronotum black, more pruinose laterally. Mesonotum black, nitidous, only the dorsopleural region restrictedly paler. Pleura black. Halteres yellow, the knobs orange-yellow. Legs with the fore coxæ black; middle coxæ darkened basally; hind coxæ and all trochanters yellow; femora with more than the basal half yellow, the remainder black, inclosing a conspicuous yellow ring about its own length before the apex; tibiæ black, the extreme base yellow; tarsi black. Wings (Plate 1, fig. 7) yellow, the base and costal region somewhat brighter; an extensive brown pattern distributed as follows: Broad seams along Rs, R_{2+3}, and R_3, confluent with the small and ill-defined stigma; cord, outer end of cells 1st M_2, and longitudinal veins beyond cord seamed with brown; broad seams on Cu_1, interrupted at base and before end of basal section of vein; broad seams at ends of both anal veins and in the axilla; veins brown; yellow in the basal and costal regions. Venation: h indistinct; Sc relatively short, Sc_1 extending to about opposite one-fourth the length of the strongly arcuated Rs, Sc_2 close to its tip; R_2 only about one-third to one-fourth of R_{1+2}; cell 1st M_2 closed; m-cu shortly before fork of M.

Abdominal tergites brownish black, the segments variegated medially and caudally with yellow, the ground color more or less restricted to large basolateral areas; genital segment and ovipositor pale reddish yellow; sternites obscure yellow; base of

sternal valves of ovipositor blackened. Ovipositor with the tergal valves unusually slender, acicular, nearly straight.

Habitat.—Formosa.

Holotype, female, Rantaizan, altitude 6,000 feet, June 3, 1927 (*S. T. Issiki*).

Limonia rantaiensis is well distinguished from allied regional species by the shining black mesothorax, short Rs, long R_{1+2}, and the wing and leg pattern.

LIMONIA (DICRANOMYIA) TRISTOIDES sp. nov.

Allied to *L.* (*D.*) *tristis* Schummel; general coloration gray, the præscutum with three brown stripes; legs chiefly brownish black, the femoral bases yellow; wings subhyaline, the stigma reduced or lacking; veins pale brown; male hypopygium with the spines of the rostral prolongation of the ventral dististyle united for a short distance at base, arising from long basal tubercles.

Male.—Length, about 5.2 millimeters; wing, 6.1.

Rostrum and palpi dark brown. Antennæ dark brown, the second segment more reddish apically; flagellum black; flagellar segments oval, the outer segments more elongate. Head light gray.

Mesonotal præscutum yellowish gray with three brown stripes, the median stripe longer and broader; scutellum brown, paler behind; postnotum gray. Pleura gray, vaguely marked with brown. Halteres long, entirely pale. Legs with the coxæ reddish brown; trochanters yellow; femora yellow at base, passing into black, most extensively blackened on fore femora, only the apices of middle and hind femora blackened; tibiæ and tarsi brownish black; legs long and relatively stout. Wings (Plate 1, fig. 8) subhyaline, the stigmal area greatly reduced or lacking; veins pale brown. Venation: Sc_1 ending opposite origin of Rs, the latter relatively long, about two and one-half times the basal section of R_{4+5}; cells 1st M_2 closed; m-cu oblique, at fork of M, shorter than the distal section of Cu_1.

Abdomen dark brown, the hypopygium chiefly obscure yellow. Male hypopygium (Plate 2, fig. 32) with the tergite, 9*t*, transverse, the caudal edge narrowly margined with chitin and provided with setæ, including a small median group; caudal margin of tergite gently emarginate. Basistyle, *b*, relatively long, with a single fingerlike lobe shorty beyond midlength, this tufted with setæ; mesal apical angle of basistyle with about four setigerous punctures but not produced into a tubercle; ventromesal lobe of basistyle large, setiferous. Dorsal dististyle, *dd*, much

stouter than in *L. subtristis*, curved to the acute apex. Ventral dististyle, *vd*, unusually low, pale, produced into the blackened rostral prolongation, the latter bearing two long black spines at near midlength, these arising from a very short common base, both from elongate basal tubercles; inner spine a little shorter than the outer. Gonapophyses, *g*, very broad, the mesal apical angle produced into a short blackened hook.

Habitat.—Manchuria.

Holotype, male, Koshurei, Kongchuling, altitude 625 feet, July 25, 1924 (*T. Yokoyama*).

Limonia tristoides is most closely alied to *L.* (*D.*) *subtristis* Alexander (northern Japan), differing especially in the details of structure of the male hypopygium, as the transverse emarginate ninth tergite, the short stout dorsal dististyle, and the low oval ventral dististyle with the long black rostral spines quite distinct in their structure and origin.

LIMONIA (GERANOMYIA) TENUISPINOSA sp. nov.

General coloration of mesonotum reddish brown, the præscutum with three narrow brownish black stripes; pleura yellow with a broad dark brown dorsal stripe; legs yellow; wings grayish yellow with a heavy, chiefly costal pattern; Sc long; m-cu far before the fork of M; abdominal tergites dark brown; male hypopygium with the spines of the rostral prolongation very long and slender, the outermost arising from a large swollen tubercle that is subequal in size to the prolongation beyond it.

Male.—Length, excluding rostrum, about 6 millimeters; wing, 7; rostrum, about 2.5.

Female.—Length, excluding rostrum, about 7.5 millimeters; wing, 7.5; rostrum, about 3.

Rostrum black; maxillary palpi black, 2-segmented. Antennæ with the basal segment black; second segment dark brown; flagellum obscure yellow, the outer segments darkened; flagellar segments short-oval, the outer segments more elongate. Head dusky gray, the narrow anterior vertex clearer gray.

Mesonotal præscutum reddish brown with three conspicuous brownish black stripes, the median stripe narrowed to a point at the suture; humeral and lateral regions more yellowish; scutal lobes extensively dark brown; median region of scutum and the scutellum reddish, slightly pruinose, with a continuous capillary brown vitta; postnotum dark plumbeous. Pleura yellow, the dorsal pleurites and membrane occupied by a broad dark brown longitudinal stripe that extends from the pronotum to the ab-

domen, including the pleurotergite. Halteres chiefly pale, the knobs weakly darkened. Legs with the coxæ and trochanters yellow; remainder of legs yellow, only the outer tarsal segments dark brown. Wings grayish yellow, with a dark brown, chiefly costal pattern; a small, scarcely evident dark seam at h; a similar area beyond this in cell Sc; a conspicuous triangular area surrounding the subcostal crossvein; extensive areas at origin of Rs and tip of Sc, these latter confluent or nearly so, especially in cell C; stigmal area very large, long-rectangular; a large area at outer end of vein R_3 and a small circular cloud at end of vein R_{4+5}; narrow and only slightly conspicuous seams at fork of Rs, anterior cord, m-cu, and outer of end cell 1st M_2; veins pale, darker in the infuscated areas. Venation: A supernumerary crossvein in cell Sc at near midlength; Sc long, Sc_1 extending to about two-thirds the length of Rs, Sc_2 at its tip; m-cu more than one-half its length before the fork of M.

Abdominal tergites uniformly dark brown, the sternites obscure brownish yellow, the caudal margins of the segments somewhat paler, the lateral margins narrowly darkened; hypopygium dark. Male hypopygium (Plate 3, fig. 33) with the ninth tergite transverse, the caudal margin with a small U-shaped emargination; setæ mostly marginal but continued to the cephalolateral portions of the tergite. Basistyle, *b*, relatively small, the ventromesal lobe small. Ventral dististyle, *vd*, large, exceeding the basistyle in size; rostral prolongation slender, bearing two spines, the outermost arising from a very large fleshy tubercle that is subequal to the apex of the rostral prolongation itself, the spine very long and slender; the second spine is close to the base of the rostrum, about two-thirds the length of the outer spine, very slender and gently curved. Dorsal dististyle, *dd*, a strongly curved sickle, the extreme tip acute and upturned. Gonapophyses, *g*, pale, the lateral margin of the mesal apical lobe with microscopic roughenings. Ædeagus large, constricted at near midlength.

Habitat.—China (Che-kiang).

Holotype, male, hills south of Ning-po, May 1, 1925 (*E. Suenson*). Allotopotype, female. Paratopotype, male.

Limonia tinuispinosa resembles *L.* (*G.*) *avocetta* (Alexander) and allied forms, being most readily separated by the somewhat remarkable structure of the male hypopygium.

LIMONIA (GERANOMYIA) SUENSONIANA sp. nov.

General coloration of mesonotum obscure yellow, the præscutum with three brown stripes; pleura yellow, with a narrow

and relatively ill-defined dorsal brown stripe; legs yellow, the terminal tarsal segments darkened; wings subhyaline, with a heavy costal brown pattern, the areas at origin of Rs and end of Sc widely separate; Sc long, Sc_1 ending nearly opposite the fork of Rs; m-cu far before the fork of M; abdominal tergites bicolorous, their apices broadly darkened; male hypopygium with the rostral prolongation of the ventral dististyle short, the two spines close together, relatively short.

Male.—Length, excluding rostrum, about 6 millimeters; wing, 6; rostrum, about 2.

Rostrum and palpi black, the former slightly paler at tips. Antennæ dark brown; flagellar segments oval to long-oval. Head gray.

Mesonotal præscutum obscure yellow with three brown stripes, the median stripe considerably narrowed behind; lateral stripes narrow, crossing the suture onto the scutal lobes; humeral and lateral regions of præscutum extensively light yellow; scutellum yellow with a brown spot medially at base; postnotum pruinose. Pleura yellow with a relatively narrow and ill-delimited dorsal brown stripe extending from the propleura to the postnotum, including the dorsal pleurotergite. Halteres pale, the knobs and a narrow subbasal ring on stem dark brown. Legs with the coxæ and trochanters yellow; remainder of legs obscure yellow, the terminal two tarsal segments dark brown. Wings (Plate 1, fig. 9) subhyaline, with a fairly heavy, chiefly costal brown pattern that is arranged much as in *tenuispinosa* sp. nov.; the areas at Rs and end of Sc are widely separated; wing tip more extensively darkened, inclosing a pale circular spot in outer end of cell R_3; cord and outer end of cell 1st M_2 interruptedly and narrowly seamed with brown. Venation: Sc very long, Sc_1 ending shortly before the fork of Rs, Sc_2 not far from its tip; m-cu nearly its own length before the fork of M.

Abdominal tergites bicolorous, the bases of the segments obscure yellow, the caudal margins broadly infuscated; subterminal segments more uniformly darkened; hypopygium chiefly dark; sternites pale yellow. Male hypopygium with the ninth tergite transverse, the caudal margin notched, the setæ chiefly confined to the lobes, not reaching the cephalic lateral portions of the tergite. Basistyle small, the ventromesal lobe low. Ventral dististyle very large and fleshy, the rostral prolongation short and blunt, bearing two spines that are placed close together at near midlength of the prolongation, the outer spine a little longer than the inner, both of moderate length, acute at tips.

Dorsal dististyle a strongly curved sickle, the tip suddenly narrowed into an acute point. Gonapophyses with the mesal apical lobe long and slender, the tips narrowed into slender acute points.

Habitat.—China (Che-kiang).

Holotype, male, hills south of Ning-po, May 1, 1925 (*E. Suenson*). Paratopotype, male.

I take great pleasure in naming this interesting crane fly in honor of the collector, Mr. E. Suenson, who has collected numerous Tipulidæ in China and Japan. It is allied to *L.* (*G.*) *semistriata* (Brunetti) and similar species of the Oriental fauna, differing especially in the venation and details of the male hypopygium. The acutely pointed gonapophyses present an unusual character in this involved genus.

LIMONIA (ALEXANDRIARIA) ARGYRATA sp. nov.

Head black, the broad front and posterior orbits silvery; mesonotal præscutum shiny castaneous, the lateral regions yellow; scutal lobes blackened; wings hyaline or nearly so, the stigma a little darker; Sc short, Sc_1 and 2d A long.

Female.—Length, about 5.5 millimeters; wing, 5.4 to 5.5.

Rostrum reddish brown, the basal segment of the maxillary palpus pale, the outer segments black. Antennæ black throughout; flagellar segments oval. Head black, the broad front and wide posterior orbits silvery.

Pronotum shiny yellow. Mesonotal præscutum shiny castaneous, the outer ends of the usual lateral stripes darker; lateral and humeral regions clear yellow; scutal lobes conspicuously blackened, the median region yellow; scutellum testaceous yellow; posnotal mediotergite dark plumbeous medially, margined with paler. Pleura yellow, the sternopleurite and anepisternum more purplish. Halteres short, pale, the knobs a little infuscated. Legs with the coxæ reddish yellow; trochanters obscure yellow; remainder of legs obscure yellow, the outer tarsal segments passing into black. Wings (Plate 1, fig. 10) hyaline or nearly so; stigma pale, scarcely darker than the ground color; veins brown. Venation: Sc short, Sc_1 ending far before the origin of Rs; Sc_1 long, about one-third longer than m-cu; Rs short, arcuated, about one-half the basal section of R_{4+5}; free tip of Sc_2 before the level of R_2; m-cu just before the fork of M; vein 2d A long, the cell wide.

Abdominal tergites dark brown, the sternites obscure yellow, the basal segments a little darker; genital segment yellow. Ovipositor with the tergal valves slender, gently upcurved.

Habitat.—Formosa.

Holotype, female, Urai, altitude about 1,500 feet, April 20, 1922 (*K. Takeuchi*). Paratopotype, female. Paratype, female, Hokuto, 1912 (*H. Sauter*); Deutschen Entomologischen Institute, through Dr. Walther Horn.

LIMONIA (THRYPTICOMYIA) BREVICUSPIS sp. nov.

Size large (wing, male, 7 millimeters or more); general coloration dark brown, the pleura and sternum paler; wings whitish subhyaline; stigma small, dark brown; free tip of Sc_2 not far before R_2, R_1 shortened; apical spur of R_{1+2} elongate; male hypopygium with the spines of the rostral prolongation of the ventral dististyle short and spikelike, placed close together at base of the prolongation.

Male.—Length, about 7 to 7.5 millimeters; wing, 7 to 5.

Rostrum obscure yellow, darker above; palpi brownish black. Antennæ brownish black, the flagellar segments elongate-oval, with pale glabrous pedicels to produce a moniliform appearance. Head dark brown.

Mesonotal præscutum brown, the humeral region paler; posterior sclerites obscure testaceous yellow. Pleura obscure yellow. Halteres dark brown, the stem paler. Legs with the coxæ and trochanters yellowish testaceous; femora brown, paler basally; tibiæ dark brown; basitarsi with about the basal two-fifths dark brown, the remainder of the segment and all remainder of tarsi except the outer segment snowy white; terminal segment darkened. Wings (Plate 1, fig. 11) whitish subhyaline, iridescent; stigma oval, relatively small, dark brown; veins nearly black, with conspicuous macrotrichia. Venation: Sc_1 ending opposite origin of Rs, Sc_2 some distance from its tip; free tip of Sc_2 far distad, R_1 being only about one-half the length of the long apical spur of R_{1+2}; cell 1st M_2 relatively large, m-cu shortly before midlength. In one specimen, the free tip of Sc_2 and R_2 are almost in alignment.

Abdominal tergites brown, the outer segments darker; sternites pale. Male hypopygium (Plate 3, fig. 34) with the rostral prolongation of the ventral dististyle, *vd*, of moderate length, broad at base, the apex narrowed, provided with a conspicuous seta; two rostral spines, placed at the base of the prolongation, only slightly separated; both spines unusually small and spikelike, subequal, the innermost forms a slightly enlarged basal swelling.

Habitat.—Japan (Riukiu Islands).

Holotype, male, Nago, altitude 30 feet, March 18, 1923 (*S. Sakaguchi*). Paratopotypes, 4 males, mostly in poor condition.

Limonia brevicuspis is the largest species of the subgenus *Thrypticomya* so far described.

LIMONIA (EUGLOCHINA) ARACHNOBIA sp. nov.

General coloration dark brown, the pleura paler; legs black, including the proximal ends of all basitarsi; wings strongly infumed, the stigma darker; Rs very short, encircling the proximal end of the stigma; cell 1st M_2 present.

Male.—Length, about 5.8 to 6 millimeters; wing, 6.5 to 6.7.

Rostrum testaceous yellow; palpi black. Antennæ black throughout. Head dark brown.

Mesonotum shiny dark brown, the lateral margins of the præscutum and median region of the scutum paler. Pleura more brownish yellow, shiny. Halteres obscure yellow at base, passing into brownish black. Legs black, the coxæ and trochanters concolorous with the pleura; porximal ends of basitarsi extensively blackened, this including from one-third to approximately one-half the length of the segment. Wings (Plate 1, fig. 12) with a strong dusky suffusion, the large oval stigma still darker; veins dark brown. Venation: Sc of moderate length for a member of this subgenus, the distance on $Sc_2 + R_1$ between Sc_2 and origin of Rs more than one-half longer than R_3; Rs very short, arcuated, bordering the proximal end of the stigma, shorter than the basal section of R_{4+5}; cell 1st M_2 relatively small, rectangular; m-cu beyond one-third the length of the cell; Cu_2 preserved to opposite one-third the length of the basal section of Cu_1.

Abdomen black, the sternites obscure yellow, except laterally and at apex.

Habitat.—Philippines.

Holotype, male, Majayjay, Laguna Province, Luzon, altitude above 500 meters, June 3, 1928 (*R. C. McGregor*). Paratopotype, male, May 28, 1928 (*R. C. McGregor*).

Limonia arachnobia is a very different species from *L.* (*E.*) *okinawensis* (Alexander), the only other regional species with similarly patterned legs.

The following notes of occurrence by Mr. McGregor are of unusual interest: "Hanging from a spider line by fore feet, in light forest." and "On horizontal line of spider web—same habitat as *Limonia* (*Thrypticomyia*) *arachnophila* Alexander and other members of the subgenus, at Lucban. Only three or

four seen here, in rather light hillside forest, away from any stream." The great value in the above observations lies in the fact that they are the first concerning this habit in any member of the subgenus *Euglochina*. Doleschall, in 1857, described as a doubtful member of the genus *Limnobia*, a species that he called *saltens*, that had the habit of hanging on horizontal strands of spider's webs. The arguments that have been made to settle whether the species was a *Thrypticomyia* or a *Euglochina* have been discussed by the writer.[3] The above notes by Mr. McGregor and a study of a copy of Doleschall's figure of *saltens* sent me by Mr. Edwards have convinced me that *saltens* certainly pertains to the subgenus *Euglochina*, as long contended by Mr. Edwards. In the light of our present knowledge of the fact that there are numerous, closely allied species of *Euglochina* in the Oriental and Ethiopian Regions, it would be very unwise to attempt to place *L. cuneiformis* de Meijere as a synonym of *saltens* without an examination of the type of the latter, if it is still extant.

LIMONIA (PSEUDOGLOCHINA) RIUKIUENSIS sp. nov.

Mesonotum dark brown, the præscutum yellowish in front; tibiæ snowy white, with two narrow brownish black rings; wings grayish, the stigma dark brown; Rs relatively long, angulated at origin; vein 2d A unusually long, exceeding the distal section of R_{4+5}; abdominal tergites dark brown, the basal segments with a yellowish median line; sternites yellow, segments four to seven, broadly dark brown at base.

Male.—Length, about 7 millimeters; wing, 6.5.

Female.—Length, about 7 to 7.5 millimeters; wing, 6.5.

Rostrum, palpi, and antennæ black. Head yellow.

Pronotum yellow. Mesonotal præscutum yellow in front and on the humeral region, the remainder dark brown; remainder of the mesonotum dark, paler medially. Pleura yellow, the sternopleurite extensively dark brown. Halteres infuscated. Legs with the fore coxæ and trochanters dark brown, the remaining coxæ and trochanters yellow; femora yellow, the tips infuscated, more broadly so on the posterior legs; tibiæ snowy white, including the setæ, the two rings brownish black, the first placed at near one-fourth the length of the segment, the second just beyond midlength; tarsi snowy white. Wings (Plate 1, fig. 13) with the ground color grayish, the costal region a little darker;

[3] Philip. Journ. Sci. 33 (1927) 299.

stigma dark brown, long-oval, the proximal end sometimes more pointed; a very narrow brown seam at origin of Rs; veins dark brown. Venation: Sc_1 ending beyond midlength of Rs, Sc_2 opposite or just beyond the origin of Rs; Rs elongate and angularly bent near origin; petiole of cell 2d M_2 nearly one-half the cell; vein 2d A of unusual length for a member of this subgenus, on basal fifth approximating the margin, thence swinging cephalad, the cell relatively long and wide, the vein beyond the anal crossvein fully one-fourth longer than the distal section of R_{4+5}.

Abdominal tergites dark brown, the basal segments with a narrow continuous yellow median vitta; incisures and lateral margins pale; sternites extensively pale yellow, the bases of segments four to seven broadly dark brown.

Habitat.—Japan (Riukiu Islands).

Holotype, male, Shuri, Okinawa, altitude about 300 feet, March 8, 1923 (*S. Sakaguchi*). Allotopotype, female. Paratopotypes, 3 females.

Closely allied to *L.* (*P.*) *bicinctipes* (Brunetti) differing in the larger size and details of coloration of the wings and abdomen. Vein 2d A is of unusual length for a member of *Pseudoglochina*.

LIMONIA (PSEUDOGLOCHINA) UNICINCTIPES sp. nov.

General coloration of mesonotum dark brown, the median area behind yellowish; all tibiæ white with a single narrow brownish black ring at near midlength; wing nearly hyaline, the stigma conspicuous, short-oval, dark brown; vein 2d A short, approximately three-fifths to two-thirds the length of the distal section of R_{4+5}; abdominal sternites uniformly pale.

Male.—Length, about 4.4 millimeters; wing, 4.7.

Female.—Length, about 5 millimeters; wing, 5.2.

Rostrum and palpi dark. Antennæ black throughout. Head pale, darker on posterior vertex, the latter area narrowly divided by a pale line.

Mesonotum dark brown, paler on the posterior portion of the præscutum, this color increasing in amount behind, on the scutellum and postnotal mediotergite including the entire sclerite except laterally. Pleura yellow, the sternopleurite darker. Halteres darkened. Legs with the coxæ pale yellow, including the fore coxæ; trochanters dark; femora slightly darkened basally, the posterior femora broadly infuscated, the fore and middle more narrowly so; tibiæ snowy white with a very narrow brownish black ring at near midlength; tarsi snowy white. Wings

(Plate 1, fig. 14) nearly hyaline, the stigma small, short-oval, dark brown; veins black. Venation: Sc_1 ending beyond mid-length of Rs, Sc_2 opposite this origin; Rs short, a little exceeding the basal deflection of R_{4+5}; m-cu at fork of M; vein 2d A short, the basal third approximating the anal margin and parallel with it, the remainder arched and thence extending straight to the margin, the entire vein beyond the anal crossvein from three-fifths to two-thirds the distal section of R_{4+5}.

Abdominal tergites brown, the basal two segments paler medially; sternites more uniformly pale brownish yellow. In the male the tergites are more darkened laterally at base, the median and caudal portions extensively pale.

Habitat.—Philippines.

Holotype, male, Badajoz, Tablas Island, Romblon Province, August 20, 1928 (*Francisco Rivera and A. C. Duyag*). Allotopotype, female.

In the single narrow dark tibial ring, *Limonia unicinctipes* agrees most closely with the larger *L.* (*P.*) *kobusi* (de Meijere) and *L.* (*P.*) *pulchripes* (Alexander). It is difficult to know how accurate is the figure given by de Meijere [4] of the wing of *L. kobusi*. The features shown of a very short petiole to cell 2d M_2 and the position of m-cu at nearly its own length beyond the fork of M are distinctive. From *L. pulchripes* the present species differs in the short Sc_1, the more oblique alignment of the elements of the anterior cord, together with the shorter Rs and the much shorter and more-arcuated vein 2d A.

HELIUS (HELIUS) TENUISTYLUS sp. nov.

General coloration of mesonotum dark brown, the pleura more chestnut brown; rostrum black; legs dark brown, the tarsi paling to yellow; wings with a faint brownish tinge, the stigma and costal margin slightly darkened; R_{2+3} long, diverging gently from R_{4+5}; m-cu at the fork of M; male hypopygium with the dististyles long and slender.

Male.—Length, excluding rostrum, about 5.5 to 6.5 millimeters; wing, 6.5 to 8; rostrum, 0.7 to 0.8.

Female.—Length, excluding rostrum, about 9 millimeters; wing, 8; rostrum, 0.8 to 0.9.

Rostrum black. Antennæ black, the outer segments more attenuated and slightly paler. Head black.

Pronotum black medially above, paler laterally. Mesonotum dark brown, the humeral and lateral regions of the præscutum

[4] Bijd. tot de Dierkunde 18 (1904) pl. 8, fig. 5.

brighter brown; extreme posteromedian region of præscutum and median portion of scutum more yellowish; remainder of notum dark brown. Pleura chestnut brown, the dorsopleural region darker. Halteres dark brown, the base of the stem narrowly yellow. Legs with the coxæ and trochanters brownish yellow; remainder of legs dark brown, the tarsi paling to yellow. Wings (Plate 1, fig. 15) with a faint brownish tinge, the stigma and costal region a little darkened; veins brownish black. Venation: R_{2+3} long, gently sinuous, diverging gently from R_{4+5}; cell 1st M_2 widest at base; m a little longer and more oblique than the basal section of M_3; m-cu at fork of M.

Abdomen brownish black. Male hypopygium (Plate 3, fig. 35) with the dististyles long and slender, the outer style, *od*, chitinized, the apex obtuse; inner style, *id*, longer, subangularly bent. Mesal face of basistyle, *b*, produced into a weakly spinous lobe.

Habitat.—Formosa.

Holotype, male, Kirakei, altitude 4,000 feet, June, 28, 1927 (*S. T. Issiki*). Allotype, female, Chipon, July 4, 1928 (*S. T. Issiki*); paratypes, 3 males, with the allotype.

Helius tenuistylus belongs to a group of closely allied forms that center about *H. nigriceps* (Edwards). The species differs from *H. nigriceps* in the longer, more gently sinuous R_{2+3} and the structure of the male hypopygium.

HELIUS (HELIUS) ATTENUATUS sp. nov.

General coloration of thorax brownish black, the pleura more brownish yellow; rostrum black; legs brownish black, the tarsi paling to brownish yellow; wings with a dusky tinge, the stigma and costal region darker brown; Sc long, Sc_2 ending opposite or beyond the fork of M; R_{2+3} long, gently sinuous; m-cu at fork of M; male hypopygium with the outer dististyle truncated to weakly bidentate at apex; inner dististyle prolonged into a slender yellowish apical portion.

Male.—Length, excluding rostrum, about 5.5 millimeters; wing, 5.5 to 5.8; rostrum, about 0.5.

Female.—Length, excluding rostrum, about 6 millimeters; wing, 5.5; rostrum, about 0.5 to 0.6.

Rostrum dark brown, palpi black. Antennæ black throughout; basal four flagellar segments larger, the remainder narrowed. Head black, the front more opaque and slightly grayish.

Pronotum and mesonotum brownish black, the median area of the scutum paler. Pleura brownish yellow, the dorsopleural

region dusky. Halteres dusky, the base of the stem very restrictedly paler. Legs with the coxæ and trochanters brownish yellow; femora and tibiæ brownish black, the tarsi paling to brownish yellow. Wings with a strong dusky tinge, the stigma and costal region darker brown; wing apex and a seam along vein Cu vaguely infumed; veins dark brown. Venation: Sc long, Sc_2 ending opposite or shortly beyond the fork of Rs, longer than Sc_1; R_{2+3} long and gently sinuous; cell 1st M_2 generally parallel-sided, the proximal end not or but slightly widened; m-cu at fork of M.

Abdomen, including the hypopygium, black. Male hypopygium (Plate 3, fig. 36) with the outer dististyle, *od*, much shorter than the inner, the apex irregularly truncate to weakly bidentate, in the latter case, the inner tooth more acute. Inner dististyle, *id*, long, the apical portion elongate, pale yellow; base of style with numerous setæ, including a fringe of four or five major bristles along the mesal edge. Basistyle, *b*, without a lobe.

Habitat.—Formosa.

Holotype, male, Chipon, July 4, 1927 (*S. T. Issiki*). Allotopotype, female. Paratopotypes, 3 males.

Helius attenuatus is closely allied to *H. nigriceps* (Edwards), differing especially in the darker coloration of the thorax and wings, the details of venation, as the long R_{2+3}, and the details of the male hypopygium, as the very long apical portion of the inner dististyle.

HEXATOMINI

PHYLLOLABIS BEESONI sp. nov.

General coloration pale testaceous yellow; legs pale yellow, the terminal tarsal segments darkened; wings with a pale brownish yellow suffusion, the base and costal region clearer yellow; cell 1st M_2 closed, m-cu at the fork of M_{3+4}; abdomen dark brown, the genitalia brighter.

Female.—Length, about 6.5 to 7 millimeters; wing, 7.2 to 8.

Rostrum pale, the palpi brown. Antennæ of moderate length, if bent backward extending to shortly beyond the base of the halteres; antennæ pale, only the outer segments a trifle darker; flagellar segments elongate, a little enlarged at bases. Head light grayish brown.

Pronotum and mesonotum testaceous yellow, the pleura a litle more yellowish. Halteres pale, the knobs a trifle darker. Legs pale yellow, the terminal tarsal segments darkened. Wings

(Plate 1, fig. 16) with a pale brownish yellow suffusion, the base and costal region clearer yellow, veins brown, the prearcular and costal veins brighter. Venation: Cell 1st M_2 closed; m-cu at the extreme outer end of the cell, opposite the fork of M_{2+4}.

Abdomen dark brown, the genital segment and ovipositor yellowish horn-color; tergal valves of ovipositor elongate and only gently upcurved.

Habitat.—British India.

Holotype, female, Mussoorie, Himalayas, altitude 6,500 feet, August, 1927 (*C. F. C. Beeson*). Paratopotype, female.

I take great pleasure in naming this interesting crane fly in honor of the collector, the Forest Entomologist, Dr. C. F. C. Beeson. *Phyllolabis beesoni* is very different from the only other known Himalayan member of the genus, *P. confluenta* Alexander.[5]

LIMNOPHILA AINO sp. nov.

Male.—Length, about 5.8 to 6 millimeters; wing, 6 to 6.5.

Closely allied to *L. dicranophragmoides* Alexander (Riukiu Islands), differing chiefly in the arrangement of the color pattern.

Antennæ with the first segment of scape black, the second obscure brownish yellow; flagellum chiefly yellow, the outer segments a little darkened. Mesonotal præscutum grayish brown, the three usual stripes entire, the median stripe wide, narrowly divided by a more grayish median vitta; lateral stripes narrow; pseudosutural foveæ and tuberculate pits black, conspicuous, the latter some distance back of the cephalic margin of the sclerite; centers of scutal lobes and the median area brown, yellowish pollinose; scutellum and postnotum brown. Pleura chiefly dark brown. Halteres yellow, the knobs conspicuously dark brown. Legs with the coxæ dark brown; remainder of legs yellow, the outer tarsal segments more infuscated; legs with conspicuous semierect pale setæ. Wings with the ground-color more whitish subhyaline, the pattern arranged in similar manner to *L. dicranophragmoides* but the individual bands more separated, especially the one at origin of Rs and the one along the cord; the latter two are separated by a wide, generally clear band that is approximately as wide as the first-mentioned dark band; dark bands of wing more compact, the pale spots and dashes within them being much reduced; along the costal margin the four or five

[5] Rec. Indian Mus. 29 (1927) 206–207, fig. 17.

outer areas are solidly darkened, not with a pale central spot as in *L. dicranophragmoides*. Venation: Sc short, Sc_1 ending opposite or shortly before the fork of Rs; inner ends of cells R_4, R_5, and 1st M_2 in oblique alignment, the last most basad; m-cu not far beyond the fork of M. Abdomen chiefly brown, the tergites darker laterally; a narrow subterminal dark ring; hypopygium reddish brown; basal sternites more reddish brown, darkened laterally and caudally, the outer segments more uniformly darkened. Male hypopygium (Plate 3, fig. 37) with the outer dististyle, *od*, appearing as a blackened rod, the tip strongly curved into a spine, the outer margin quite smooth, the inner margin, in the axil of the terminal spine, with a few microscopic denticles. Inner dististyle, *id*, very broad, mitten-shaped. Gonapophyses, *g*, appearing as pale rods, the apex of each dilated into an oval head.

Habitat.—Japan (Hokkaido).

Holotype, male, Jozankei, altitude about 1,000 feet, July 29, 1923 (*S. Kuwayama*). Paratopotypes, 9 males, mostly in poor condition.

ERIOPTERINI

CLADURA ALPICOLA sp. nov.

General coloration pale yellow; legs yellow, the extreme tips of the femora and tibiæ infuscated; tarsi extensively brownish black; wings pale yellow; a tiny black spot at extreme base of wing; male hypopygium large and complex, the basistyle with a large mesal lobe that is unequally bilobulate near tip; inner dististyle with a conspicuous basal shoulder.

Male.—Length, 7.5 to 8 millimeters; wing, 8.5 to 9.

Head, thorax, and abdomen with long conspicuous pale setæ. Rostrum brownish yellow, palpi darker. Antennæ with the basal segment dark brown, in some cases so colored only basally, the remainder yellowish; outer flagellar segments darker; verticils elongate. Head pale brownish yellow, more rarely darker, grayish brown.

General coloration of prothorax and mesothorax pale yellow, immaculate. Halteres pale, the knobs weakly darkened. Legs with the coxæ and trochanters pale yellow; femora yellow, the extreme tips infuscated, tibiæ yellow, the tips narrowly darkened; tarsi extensively brownish black; legs conspicuously hairy. Wings (Plate 1, fig. 17) pale yellowish; a single tiny black dot at extreme wing base above the squama; veins brown, the prearcular and costal veins more yellowish. Macrotrichia of veins long

and conspicuous. Venation: Sc_1 relatively short, only a little longer than Sc_2; Rs long, gently arcuated; R_{2+3+4} shorter than cell 1st M_2; petiole of cell M_1 subequal to or considerably exceeding m; m-cu from one-half to nearly its own length beyond the fork of M; vein 2d A long, very gently sinuous.

Abdomen yellow, the tergites with narrow, interrupted median and lateral dusky stripes, in cases including the subcaudal portions of the segments; sternites similar, their caudal margins darkened; hypopygium pale. Male hypopygium (Plate 3, fig. 38) very large and complicated in structure, much as in *C. megacauda*, differing especially in the structure of the tergite, basistyle, and dististyle. Basistyle, *b*, with the mesal lobe large, flattened, at apex somewhat expanded, on outer margin before apex with a small fingerlike lobe terminating in a small pencil of setæ. Outer dististyle, *od*, very long and pale, slender, considerably longer than the inner style, setiferous, with larger setæ at apex. Inner dististyle, *id*, distinctly bilobed, there being a stout basal shoulder, the more slender inner arm truncate at apex. Gonapophyses, *g*, taken together appearing lyriform, relatively slender, the obliquely truncated apex weakly toothed.

Habitat.—Japan (Honshiu).

Holotype, male, Yarigatake, Japanese Alps, August 24, 1925 (*Jiro Machida*). Paratopotypes, 4 males; paratypes, 3 males, Tsubakuro, Japanese Alps, August 23, 1925 (*Jiro Machida*).

Claudura alpicola is most closely allied to *C. megacauda* Alexander (Hokkaido, Japan), differing especially in the details of structure of the male hypopygium. These two species belong to a distinct group of the genus that can scarcely be referred to the subgenus *Neocladura* Alexander, the only other division of the genus in which the male hypopygium possesses two dististyles.

GYMNASTES CATAGRAPHA sp. nov.

? Teucholabis sp. nov. BRUNETTI, Rec. Indian Mus. 15 (1918) 306.

Head orange; mesonotum yellowish, the præscutum with a median black stripe; knobs of halteres orange-yellow; femora with a yellow subterminal ring; wings whitish subhyaline, with three brown crossbands; abdominal tergites dimidiate orange and dark brown.

Male.—Length, about 6.5 millimeters; wing, 5.7.

Rostrum shiny reddish yellow; palpi brownish black. Antennæ with the basal segment orange; second segment brown, paler at base; flagellum brownish black; flagellar segments elongate-

oval to subcylindrical, with elongate verticils. Head broad, obscure orange.

Pronotum obscure orange-yellow. Mesonotal præscutum yellow, the median stripe shiny black, the lateral stripes reddish, poorly delimited; scutum shiny yellow medially, each lobe with a blackened spot near mesal portion, the remainder reddish; scutellum brownish black, brighter basally; postnotum blackened, paler laterally. Pleura badly injured by the pin, the propleura reddish brown, the mesopleura apparently darker brown, variegated with paler. Halteres dusky, the knobs orange-yellow. Legs with the coxæ and trochanters reddish yellow; femora obscure yellow, the distal half passing into dark brown, with a conspicuous subterminal yellow ring that is a little narrower than the darkened tip; tibiæ brown, becoming darker brown toward the tip; tarsi brown, the distal segments darker. Wings (Plate 1, fig. 18) whitish subhyaline, the prearcular and costal region more yellowish; a heavy brown pattern, appearing as three crossbands; basal band narrow, almost parallel-sided, extending from R at the origin of Rs to the anal margin at the end of vein 2d A, very narrowly interrupted in cell R adjoining vein M; the second band includes the cord, widened out at the stigmal region, narrower along the cord, again widened out but much paler in the outer end of cell Cu; the third band includes the wing-tip in cells R_3, R_4, R_5 2d M_2, and M_3, the inner margin nearly straight; a broad additional seam at the outer end of cell 1st M_2; veins pale brown, a little darker in the infuscated areas. Venation: Sc_1 ending shortly before the fork of Rs, Sc_2 some distance from the tip of Sc_1; R_{2+3+4} a little longer than R_2 alone; R_{2+3} punctiform; R_2 directed a little basad, about one-half R_{1+2}; veins R_3 and R_4 widely divergent, the former about one-half the latter; cells R_4, R_5, and 1st M_2 in slightly oblique alignment; cell 1st M_2 rectangular, a little widened outwardly; m-cu less than its length beyond the fork of M.

Abdominal tergites conspicuously dimidiate, the basal two-thirds of each segment dark brown, the remainder orange; sternites similar but the dimidiate appearance not so conspicuous, especially on the basal segments where the ground color is pale brown, the incisures broadly orange; on the subterminal segments the colors are more contrasted; hypopygium obscure fulvous; no sternal pouch. Male hypopygium (Plate 3, fig. 39) very small; caudal margin of the tergite convex. Basistyle, *b*, rela-

tively large, the outer angle produced, the dististyles being placed on the mesal face of the style at near midlength; two small blackened combs on the style. Outer dististyle a flattened blade, the outer angle at base darkened and microscopically roughened; apex obtuse, darkened, sparsely setiferous, the margin with microscopic serrulations. Inner dististyle smaller, the margins smooth, before the apex with a powerful bristle. Ædeagus, *a*, very large, appearing as a conspicuous pale blade that juts caudad beyond the other elements of the hypopygium, the apex obtuse but extended into a short point on the ventroapical portion; distal portion of ædeagus with conspicuous setæ.

Habitat.—Southwest India.

Holotype, male, Castle Rock, North Canara District, October 11 to 26, 1916 (*S. Kemp*). Type in the collection of the Indian Museum.

Gymnastes catagrapha is allied to *G. demeijerei* (Riedel),[6] differing in the chiefly yellow body coloration, as well as in the differently colored halteres and legs.

STYRINGOMYIA TABLASENSIS sp. nov.

General coloration yellow, variegated with brownish black; head gray; femoral dark rings incomplete; wings yellow, with four separate dark areas; vein 2d A simple, the apex gently curved; male hypopygium with the ninth sternite deeply bilobed at apex; outer arm of dististyle a long rod that narrows gradually to the acute simple apex.

Male.—Length, about 4 millimeters; wing, 4.2.

Antennal scape dark, the flagellum conspicuously paler. Head gray.

Pronotum brownish black, narrowly paler medially; posterior notum paler laterally. Mesonotal præscutum with the median portion brownish black, the posterior two-thirds fulvous-yellow with a sinuous black line on either side of the more cinerous median area; scutal lobes and median area chiefly pale, completely margined laterally and caudally with black; scutellum black, the median area restrictedly pale; postnotal mediotergite brownish black. Pleura pale, yellowish, the color including the pleurotergite. Halteres pale yellow. Legs with the coxæ and trochanters yellow; femora yellow with two narrow incomplete dark rings, as usual in the genus, the ventral surface of the femora immaculate; tibiæ yellow, the tips darkened; tarsi yellow,

[6] Ann. Mus. Nat. Hung. 18 (1921) 135–136, new name for *Gnophomyia fascipennis* de Meijere, Bijd. tot de Dierkunde 21 (1919) 15, preoccupied.

the last segment black. Wings with a yellowish suffusion; four dark brown areas, as follows: A large oval area centering about r-m, including the extreme bases of the adjoining veins; fusion of M_{2+1} and M_3; m-cu; distal third of vein 2d A; veins yellow, brownish black in the infuscated areas. Venation: A short fusion of M_3 with M_{1+2} beyond cell 1st M_2; vein 2d A gently curved to the margin.

Abdominal tergites yellow, each segment with two brown spots at caudal margin, on the seventh segment becoming larger and confluent; eighth segment with a longitudinal brown median stripe; hypopygium chiefly pale; sternites more uniformly pale yellow. Male hypopygium (Plate 3, fig. 40) with the ninth tergite, 9*t*, a broad pale setiferous lobe, the apex very insensibly bilobed. Ninth sternite, 9*s*, very deeply bilobed, each lobe bearing a very long seta. Basistyle, *b*, with the outer apical angle a slender pale lobe that bears a slender seta that is longer than the lobe itself. Dististyle, *d*, very complex, the outer arm a long rod, its base wide and pale, the outer end narrowed to the acute gently curved apex, entirely without a long apical seta, as in many species of the genus. Two arms, gently curved and more or less opposed to one another, bearing series of peglike spines, those of the outer arm (about 15) more crowded, of the inner or cephalic arm (about 9) more scattered; other lobes of the complex dististyle include a simple boomerang-shaped structure and a broad-based lobe that is tipped with one or two powerful black spines and bears a long powerful seta before apex.

Habitat.—Philippines.

Holotype, male, Badajoz, Tablas Island, Romblon Province, August 27, 1928 (*Francisco Rivera and A. C. Duyag*).

STYRINGOMYIA NIPPONENSIS sp. nov.

Male.—Length, about 5.5 millimeters; wing, 5.2.

Closely allied to *S. formosana* Edwards, differing especially in the structure of the dististyle of the male hypopygium.

Second segment of scape dark brown, the base paler. Largest setæ of head black, a few smaller ones yellow. Menosotal præscutum dark brown, with longitudinal paler stripes, the dark areas of the interspaces interrupted at the level of the pseudosutural foveæ; posterior median region of præscutum, median area of scutum, and central portion of scutellum yellow, scutal lobes reddish brown, encircled by darker, each with an erect seta near mesal edge; disk of scutellum with an erect seta on each side of the yellowish median area; postnotum darkened. Pleura

pale yellow. Halteres pale, the knobs weakly infuscated. Legs with the dark areas on femora narrow and restricted to the dorsal portion; medial tibial ring similarly incomplete, the apical ring narrow but entire; basal four tarsal segments almost white, incisures weakly darkened; terminal segment black. Wings with a yellowish suffusion, the base and costal region brighter; a circular dark spot on r-m; less distinct dark seams on m-cu, outer end of cell 1st M_2 and distal third of 2d A; medial veins beyond cord chiefly darkened; radial, costal, and cubital veins pale. Venation: R_{2+3+4} oblique; m-cu nearly its own length beyond fork of M; vein 2d A bent strongly at end, subangulate but unspurred. Abdominal tergites obscure yellow; basal segment dark; succeeding segments with paired dark spots on caudal margins and less distinct ones on basal ring of segment; segment 7 with a median darkening; hypopygium chiefly pale. Male hypopygium with the dorsal apical lobe of basistyle with a longer and more hairlike apical bristle. Dististyle with the outer lobe long and slender, the apical seta long, as in *formosana;* anterior lobes of dististyle (Plate 3, fig. 41) broad at base, one narrowed apically into an acute pale point, the apical margin with two or three groups of blackened pegs, the more proximal of these arranged more or less in the form of a crescent; innermost lobe of dististyle with the apex obtuse, the outer caudal angle with numerous black peglike spines that decrease in size and become more separated outwardly; surface of style basad of these pegs with very long, basally directed setæ. Ninth sternite very narrow, entire, with the usual two apical setæ.

Habitat.—Japan (Honshou).

Holotype, male, Asahara, June 1, 1925 (*C. Harukawa*).

It may be noted that *Styringomyia formosana* Edwards has been taken as far north as Tokyo (May 14, 1919, *R. Takahashi*) and is thus the most northerly record for the genus.

ILLUSTRATIONS

[Legend: *a*, ædeagus; *b*, basistyle; *d*, dististyle; *dd*, dorsal dististyle; *g*, gonapopyhysis; *id*, inner dististyle; *od*, outer dististyle; *s*, sternite; *t*, tergite; *vd*, ventral dististyle.]

Plate 1

Fig. 1. *Brithura sancta* sp. nov., wing.
2. *Brithura conifrons* Edwards, wing.
3. *Tipula rantaicola* sp. nov., wing.
4. *Tipula microcellula* Alexander, wing.
5. *Nesopeza rantaizana* sp. nov., wing.
6. *Oropeza bispinula* sp. nov., wing.
7. *Limonia* (*Limonia*) *rantaiensis* sp. nov., wing.
8. *Limonia* (*Dicranomyia*) *tristoides* sp. nov., wing.
9. *Limonia* (*Geranomyia*) *suensoniana* sp. nov., wing.
10. *Limonia* (*Alexandriaria*) *argyrata* sp. nov., wing.
11. *Limonia* (*Thrypticomyia*) *brevicuspis* sp. nov., wing.
12. *Limonia* (*Euglochina*) *arachnobia* sp. nov., wing.
13. *Limonia* (*Pseudoglochina*) *riukiuensis* sp. nov., wing.
14. *Limonia* (*Pseudoglochina*) *unicinctipes* sp. nov., wing.
15. *Helius* (*Helius*) *tenuistylus* sp. nov., wing.
16. *Phyllolabis beesoni* sp. nov., wing.
17. *Cladura alpicola* sp. nov., wing.
18. *Gymnastes catagrapha* sp. nov., wing.

Plate 2

Fig. 19. *Brithura sancta* sp. nov., male hypopygium.
20. *Tipula subfutilis* sp. nov., male hypopygium.
21. *Tipula subfutilis* sp. nov., male hypopygium, ninth tergite.
22. *Tipula futilis* Alexander, male hypopygium, ninth tergite.
23. *Tipula futilis* Alexander, male hypopygium.
24. *Tipula yusouoides* sp. nov., male hypopygium.
25. *Tipula subyusou* sp. nov., male hypopygium, gonapophysis.
26. *Tipula yusou* Alexander, male hypopygium, gonapophysis.
27. *Nesopeza idiophallus* sp. nov., male hypopygium, ædeagus.
28. *Oropeza satsuma* Alexander, male hypopygium.
29. *Oropeza satsuma* Alexander, male hypopygium, ninth tergite.
30. *Oropeza bispinula* sp. nov., male hypopygium.
31. *Oropeza bispinula* sp. nov., male hypopygium, ninth tergite.
32. *Limonia* (*Dicranomyia*) *tristoides* sp. nov., male hypopygium.

Plate 3

Fig. 33. *Limonia* (*Geranomyia*) *tenuispinosa* sp. nov., male hypopygium.
34. *Limonia* (*Thrypticomyia*) *brevicuspis* sp. nov., male hypopygium.

FIG. 35. *Helius* (*Helius*) *tenuistylus* sp. nov., male hypopygium.
36. *Helius* (*Helius*) *attenuatus* sp. nov., male hypopygium.
37. *Limnophila aino* sp. nov., male hypopygium.
38. *Cladura alpicola* sp. nov., male hypopygium.
39. *Gymnastes catagrapha* sp. nov., male hypopygium.
40. *Styringomyia tablasensis* sp. nov., male hypopygium.
41. *Styringomyia nipponensis* sp. nov., male hypopygium, dististyles.

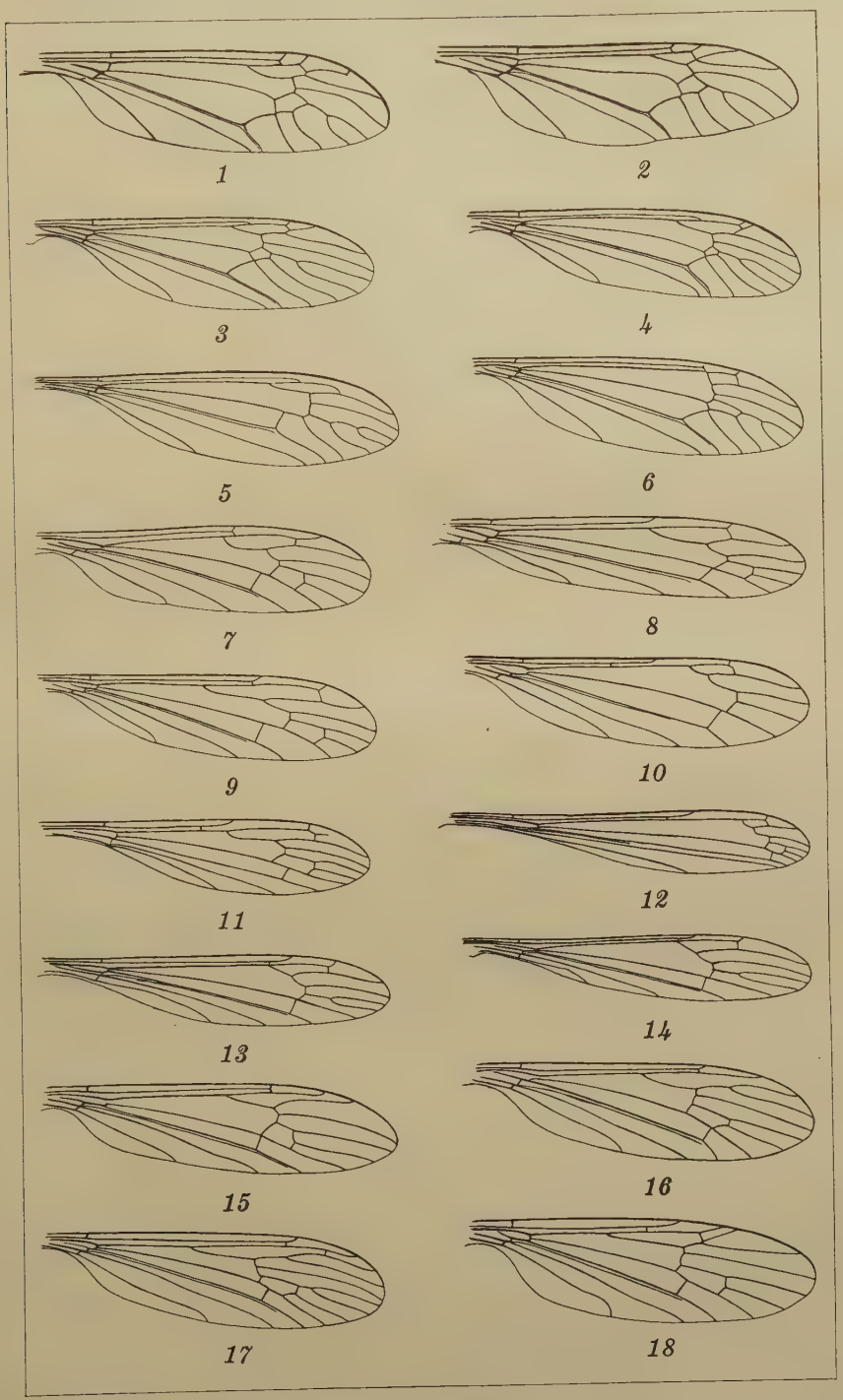
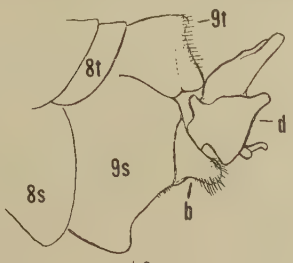


PLATE 1.



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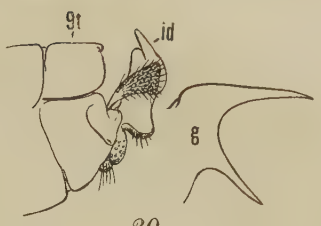

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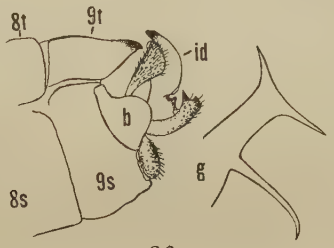

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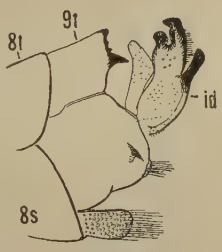

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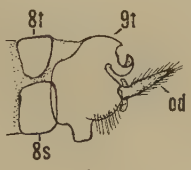

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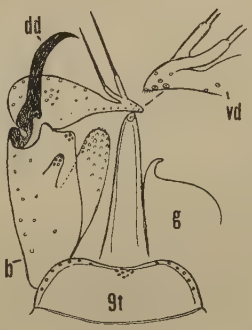

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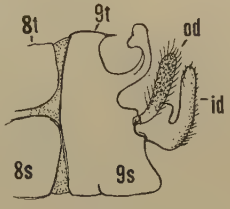

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PLATE 2.

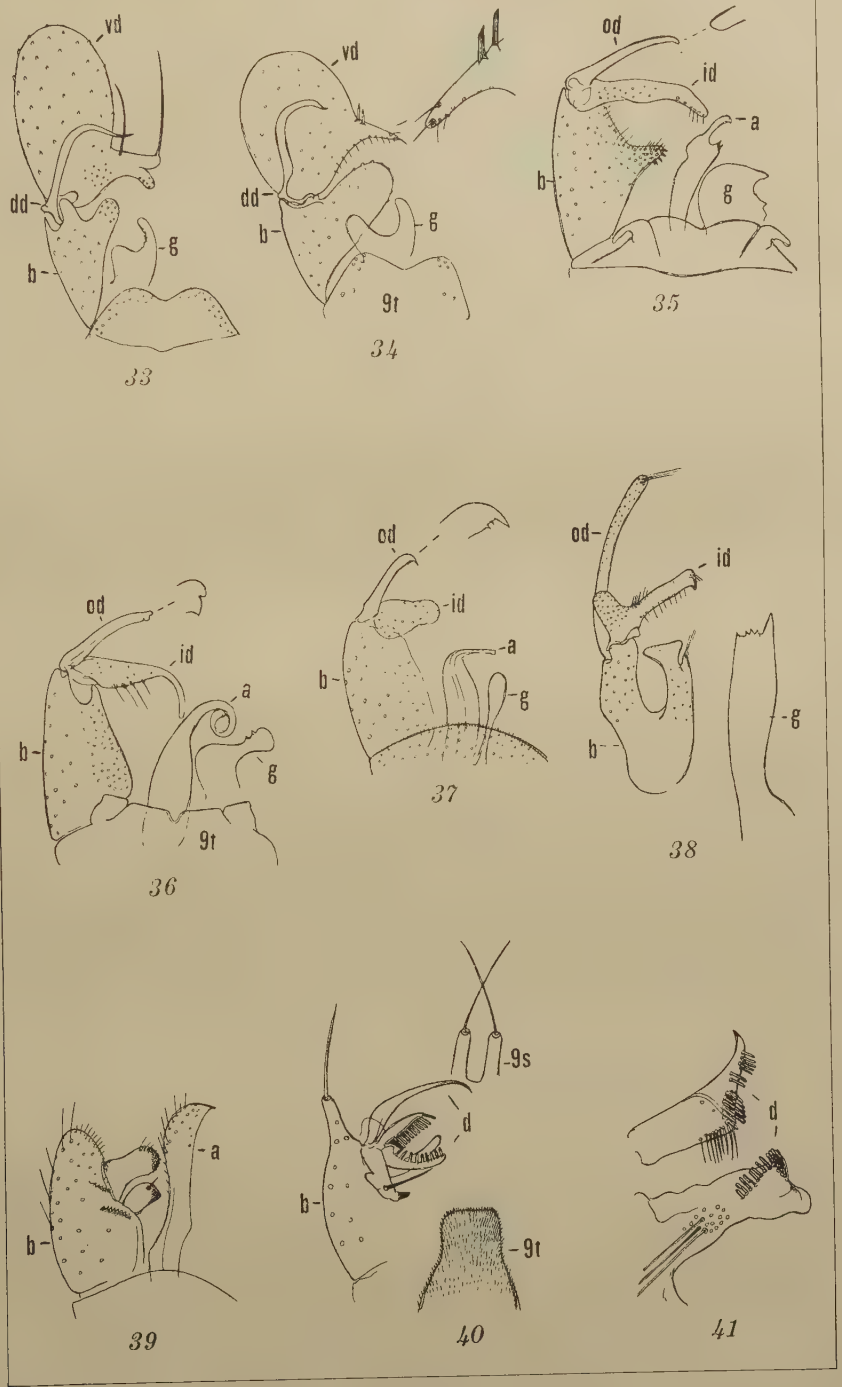
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PLATE 3.

COMPOSITION OF PHILIPPINE COFFEE

By Abelardo Valenzuela

Of the Bureau of Science, Manila

Some years ago the growing of coffee in the Philippines was an important and promising industry. At one time there was an average annual export of about 7,000 tons [1] of coffee valued at 4,000,000 pesos. The advent of the coffee blight, *Hemileia vastatrix*, practically destroyed the coffee industry. In 1913, the Philippines produced only 113,031 kilograms of coffee. In 1927 the export of Philippine coffee was only 96 kilograms, while the total imports were valued at 1,714,595 pesos.[2] Formerly the Arabian coffee was the principal species cultivated in the Philippines. This species of coffee suffered so severely from the coffee blight that it would seem advisable in starting new plantations to use a more resistant species such as Robusta, Liberica, or Excelsa. These coffees seem to be satisfactory substitutes for the Arabian species; and although they are not immune to the blight, they are so resistant that notwithstanding the presence of the blight they grow well and produce abundant crops. Again, these coffees thrive under more varied conditions than the Arabian coffee. In Java, where the Robusta coffee is planted very extensively, permanent shade is considered advisable. Some of the shade trees considered suitable for coffee are the ipil-ipil, which is the best, and the madre de cacao, dapdap, and guango. A good account of the agriculture of Robusta and other species of coffee is given by Wester [3] and also by David and Baker.[4]

The samples of Philippine coffee used in this investigation were obtained from the Philippine Bureau of Agriculture. Seven species were analyzed. They were the Robusta, *Coffea robusta* Linn.; Liberica, *Coffea liberica* Hiern; Canephora, *Coffea canephora* Pierre; Abeota, *Coffea abeocuta* Cr.; Excelsa, *Coffea excelsa* A. Chev.; Uganda, *Coffea ugandæ* Cr.; and Arabian,

[1] Wester, P. J., Philip. Agr. Rev. 8 (1915) 39.
[2] Annual Report, Insular Collector of Customs, Manila (1927).
[3] Philip. Agr. Rev. (1918) 129.
[4] Philip. Agr. Rev 17 (1928) 65.

Coffea arabica Linn. A brief description of these coffees and the trees from which they are obtained is given by Wester.[5]

Coffea robusta is a small tree which is adapted to a reasonably friable and fertile soil. It requires abundant rain, and grows best at altitudes ranging from 450 to 700 meters. It yields from 875 to 1,800 kilograms of coffee per hectare, but the coffee requires artificial drying. *Coffea canephora* and *Coffea ugandæ* are closely related to Robusta and have similar requirements.

Coffea liberica is a small tree adapted to elevations of 350 meters or less. It succeeds well on rather heavy, clayey soils and yields about 650 kilograms of coffee per hectare. When properly prepared, the coffee is of good quality. *Coffea abeocuta* and *Coffea excelsa* have requirements similar to Liberica to which they are closely related. However, Abeota, and Excelsa coffees yield berries much smaller than those of Liberica.

Coffea arabica is common throughout the Philippines, but of no importance except in the highlands of Mindanao and northern Luzon, and even there the production is limited owing to the coffee blight.

In Table 1 is given the composition of various Philippine raw coffees. In anayzing these coffees the usual standard methods of analysis were employed.[6] The caffeine, however, was determined by the modified Stahlschmidt method.[7]

TABLE 1.—*Composition of Philippine raw coffees.*

Constituent.	Robusta.	Liberica.	Canephora.	Abeota.	Excelsa.	Uganda.	Arabian.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	8.11	8.18	11.72	8.93	10.49	10.48	11.08
Caffeine	1.79	1.69	2.42	1.74	1.83	2.06	1.62
Fat	9.36	9.69	7.39	9.10	9.54	7.41	8.20
Reducing sugar	4.08	4.75	6.35	6.85	4.55	6.05	3.97
Crude fiber	18.57	17.86	25.80	17.66	22.80	18.38	16.52
Nitrogenous substances	13.70	15.01	11.26	11.96	13.12	12.54	13.00
Ash	4.57	4.09	4.33	3.69	3.47	4.05	4.44
Other non-nitrogenous substances (by difference.)	39.82	38.46	30.73	40.07	34.20	39.03	41.17
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[5] Bull. P. I. Bur. Agr. 39 (1925) 62.

[6] Methods of Analysis of the Association of Official Agricultural Chemists (1924) 333.

[7] Fuller, H. C., Chemistry and Analysis of Drugs and Medicines (1920) 289.

In Table 2 is given the average composition of Philippine and foreign raw coffees.

TABLE 2.—*Composition of Philippine and foreign raw coffees.*

	Philippine coffees.	Foreign coffees. [a]
	Per cent.	*Per cent.*
Moisture	9.86	11.23
Caffeine	1.87	1.21
Fat	8.71	12.27
Reducing sugar	5.22	8.55
Crude fiber	19.65	18.17
Nitrogenous substances	12.95	12.07
Ash	4.10	3.92
Other non-nitrogenous substances (by difference)	37.64	32.58
Total	100.00	100.00

[a] Leach, A. E., Food Inspection and Analysis (1920) 393.

As shown by the data (Table 2) the Philippine raw coffees seem to compare favorably in composition with foreign raw coffees. Raw Philippine coffee contains a slightly higher percentage of caffeine than the foreign raw coffees. The foreign coffee, however, contains a somewhat higher percentage of fat and reducing sugar.

SUMMARY

Seven varieties of Philippine raw coffee were analyzed. The results seem to indicate that in composition Philippine coffees compare favorably with foreign coffees.

EFFECTS OF SPLENECTOMY UPON THE PRODUCTION OF ANTIBODIES IN DOGS

By Hilario Lara and Carmelo Reyes

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INTRODUCTION

The function of the spleen has been studied from various angles in the past, but it is only recently that attempts have been made to determine the influence that this organ exerts upon bodily resistance against certain forms of definite harm.

De Boer and Carrol [1] in their carbon monoxide (Co) poisoning experiments suggested that the function of the splenic contraction was to expel unpoisoned red cells into the blood and so reduce the proportion of carbon monoxide hæmoglobin (COHb) to hæmoglobin dioxide (HbO_2) in the general circulation.

Barcroft, Murray, et al.[2] showed that, in an atmosphere which received a continuous accession of coal gas, splenectomized guinea pigs died sooner than either normal guinea pigs, or those from which a piece of the omentum has been removed, or those from which one horn of the uterus has been excised.

Singer [3] in 1925 reported on a breach of natural immunity affected by blockade of the reticulo-endothelial system.

Lewis and Margot [4] in 1914 published descriptions of experiments which seemed to show that splenectomy greatly increased the resistance of albino mice to infection with *Bacillus tuberculosis,* but later Murphy and Ellis [5] were able to explain this seemingly anomalous result. They found that mice splenectomized a short time prior to inoculation with *B. tuberculosis* were distinctly more susceptible than normal animals; while, with the increase of the interval between splenectomy and infection, the mice gradually showed greater resistance than

[1] Journ. Physiol. 59 (1924–1925) 312.
[2] Journ. Physiol. 60 (1925) 79.
[3] Cited by Jungeblutt, Journ. Exp. Med. 46 (1927) 609–613.
[4] Ibid.
[5] Ibid.

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[5] Ibid.

the controls. They attributed this increased resistance to a secondary hypertrophy of the remaining lymphoid tissue.

Our experiment is an attempt to determine the effect of the removal of the spleen on the production of agglutinins in the blood stream of experimental animals shortly after recovery from splenectomy operations.

EXPERIMENTS

Operations.—In the experimental work that forms the basis of this paper, twenty-two dogs have been splenectomized, of which the first series of seven was operated on between July 7 and 28, 1925, but were not experimented upon, the animals having developed some kind of skin eruptions (presumably from ticks with which they were afflicted) which it was feared might influence the results. Therefore, it is the second series of dogs (fifteen in all) operated upon between June 16 and July 7, 1928, that has been chiefly depended on for this study.

All of the operations were performed under ether anæsthesia. There was nothing unusual in the technic. The three main branches of the artery in the gastrosplenic omentum were separately ligated previous to the extirpation of the organ and in some cases religated en bloc. After losing an uruly dog (presumably from a secondary postoperative hæmorrhage on the third day) chromicized catgut was substituted for plain catgut in the ligation of the splenic vessels in some of the cases. The same material was used for the skin, as abacá, our local skin-suture material, had not proved strong enough in some of the preceding operations.

Except in the one case no blood was lost; there was no operative difficulty, and the whole procedure averaged a quarter of an hour each time. Stitches were removed on the tenth day, and wounds healed by first intention.

Animal have been splenectomized on an average twenty-two days before preliminary titration, thirteen and twenty-seven days being the extremes; forty-two days to the date of the first injection, August 2; forty-six days to August 6; fifty-one days to August 11; and fifty-seven days to August 17, the date of serum titration.

With the exception of three dogs that refused to eat one or two days before their death, and appeared to become weaker, lying down in their cages most of the time, and having profuse lachrymal secretions which dried up and accumulated about their eyelids, the dogs did not appear to be visibly ill. Two of them appeared to have difficulty of micturition.

The average duration of postoperative life was thirty-six days; the extremes were ten days (exclusive of the dog dying of secondary hæmorrhage) and eighty-seven days.

Of the fifteen splenectomized dogs in our second series fourteen recovered and one died presumably from active secondary hæmorrhage, a large amount of dark fluid blood having been found in its abdominal cavity. Of the fourteen splenectomized dogs that recovered one escaped forty-two days after operation in very strong condition; in fact, it was the liveliest of the group. Of the thirteen that remained for immunization, nine died after the removal of blood for titration prior to immunization.

Of all the animals experimented upon in 1928, second series (fifteen splenectomized and six nonsplenectomized for control), only four splenectomized and four nonsplenectomized lived long enough to have their serums titrated after immunization.

Immunization and titration.—Cholera vaccine (containing 1,000 million killed organisms per cubic centimeter of sterile salt solution), preserved with 0.5 per cent phenol, was used for immunizing the control (nonsplenectomized) and the splenectomized animals. Each dog of the splenectomized and the nonsplenectomized groups, practically at the same time, was given a dose of 0.20 cubic centimeter of the above-mentioned vaccine per kilogram of body weight hypodermically on the side, three times at intervals of from five to six days.

One week after the last dose of the vaccine about 5 cubic centimeters of blood were removed under aseptic precaution from the femoral vein of each dog, and the samples of blood were placed in separate test tubes and allowed to clot. The clots were separated from the sides (aseptically), and the tubes were placed in a refrigerator and allowed to stand overnight. The next day the serum was separated from the clot and $\frac{1}{10}$, $\frac{1}{50}$, $\frac{1}{100}$, $\frac{1}{150}$, $\frac{1}{200}$, $\frac{1}{250}$, $\frac{1}{300}$, $\frac{1}{350}$, $\frac{1}{400}$, $\frac{1}{450}$, $\frac{1}{500}$, $\frac{1}{550}$, $\frac{1}{600}$, and $\frac{1}{650}$ dilutions of each sample were prepared. One-half cubic centimeter of each of these dilutions was placed in a separate sterile serological test tube and an equal amount of saline emulsion of a 24-hour-old culture of cholera vibrio added, the resulting final dilution, therefore, being twice each of those above indicated. The mixture was shaken very thoroughly, incubated for eighteen hours, and the titer read.

TABLE 1.—*Effect of splenectomy upon antibody production in dogs.*

Dog.	Preliminary titer.		Immunized August 2, 1928.		Immunized August 6, 1928.		Immunized August 11, 1928.	
	Date.	Titer.	Body weight.	Dose of vaccine.	Body weight.	Dose of vaccine.	Body weight.	Dose of vaccine.
			Kg.		*Kg.*		*Kg.*	
NONSPLENECTOMIZED (NORMAL).								
A	July 31		6.00	1.20	6.10	1.22	5.90	1.18
B	July 31		10.50	2.10	11.30	2.26	10.0	2.00
C	July 31		7.60	1.52	8.35	1.67	7.50	1.500
D	July 31		8.60	1.72	9.05	1.81	9.00	1.800
SPLENECTOMIZED.								
1	July 13		10.35	2.07	10.73	2.14	10.70	2.14
2	July 13		5.45	1.09	5.98	1.19	5.85	1.17
3	July 13		11.70	2.34	12.55	2.51	12.50	2.50
4	July 13	1/50	6.50	1.30	7.25	1.45	6.80	1.36

NONSPLENECTOMIZED (NORMAL).

Dog.	Serum titer August 17, 1928.													Remarks.
	1/20	1/100	1/200	1/300	1/400	1/500	1/600	1/700	1/800	1/900	1/1000	1/1100	1/1200	1/1300	
A	+	+	+	+	+	+									Died September 20, 1928.
B	+	+	+	+	+	+	+	+	+	+					Survived till given away.
C	+	+	+	+	+										Died August 26, 1928.
D	+	+	+	+	+	+	+	+	+	+	+	+	+		Died September 18, 1928.
SPLENECTOMIZED.															
1	+	+	+	+											Died September 13, 1928.
2	+	+	+	+											Died September 4, 1928.
3	+	+	+	+	+	+	±								Died September 18, 1928.
4	+	+	+	+											Died August 31, 1928.

RESULTS

The results of the experiments from the surviving animals are presented in Table 1. In this table are shown the date when the preliminary titer was made of the blood of the splenectomized and nonsplenectomized dogs prior to immunization; the date and the dose of vaccine administered to the animals at stated intervals; and the titer of the serums after immunization. The data for the rest of the animals used in these experiments are not presented in view of the fact that the animals died before observations useful for our purposes could be made of them.

The titer of the serums of the nonsplenectomized dogs are as follows: Dog A, $\frac{1}{500}$; dog B, $\frac{1}{900}$; dog C, $\frac{1}{400}$; dog D, $\frac{1}{1200}$.

The titer of the serums of the splenectomized dogs are as follows: Dog 1, $\frac{1}{300}$; dog 2, $\frac{1}{300}$; dog 3, $\frac{1}{600}$; dog 4, $\frac{1}{300}$.

CONCLUSIONS

1. Twenty-two dogs were splenectomized, seven in 1925 (first series) and fifteen in 1928 (second series). The second series, with six more nonsplenectomized dogs, constitutes the basis of this report. In this study only four splenectomized and four nonsplenectomized dogs lived long enough to have their serums titrated after immunization.

2. Judging from our limited experience, splenectomy in presumably normal dogs seems to affect unfavorably antibody production (agglutinins) shortly after the immunization.

A GEOLOGICAL STUDY OF THE ANGAT-NOVALICHES REGION

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TWENTY-EIGHT PLATES AND THREE TEXT FIGURES

INTRODUCTION

The study of the geology of the Angat-Novaliches region was undertaken primarily for the purpose of supplying the Metropolitan Water District with geologic cross-sections along the proposed tunnel lines between their Ipo dam site on Angat River and the Novaliches reservoir site in connection with the Angat water system project. A report has already been submitted to the Metropolitan Water District covering briefly such topics as stratigraphy, structure, and general geology, and giving a more-detailed discussion of the points which concern their project from a geologic standpoint.

The present paper is a detailed study of the geology of the region with special emphasis on the structure. The most violent earthquakes have been occasioned by sudden movements or slips between portions of the earth's crust along fault planes. It is necessary to make a detailed study of the structure of a region, with a careful mapping of every fault and a study of its probable directions of movement and activities, in order to find the probable centers and directions of the shocks of future tectonic earthquakes in that region.

At the same time, some important points in Philippine geologic history have been cleared in this paper, since the Angat-Novaliches region is an unusually good representative of Philippine general geology.

FIELD WORK AND ACKNOWLEDGMENTS

The writer, assisted by Ramon F. Abarquez, made three trips. The first one, from March 24 to 28, 1924, was a brief reconnaissance along one of the proposed tunnel lines of the Metropolitan Water District. The second trip was made from September 16 to 22, 1924. Trips were made upstream on Angat River and Ipo River. Outcrops were plentiful and the sections

were studied carefully. While shooting the Angat River rapids on a bamboo raft from the Ipo dam site downstream to Norzagaray, we observed and carefully noted a well-exposed section. This section served to establish a tentative stratigraphic column, which was revised as the work progressed. During the third trip, November 22 to December 20, 1924, the geology, stratigraphy, and structure of the region were studied in detail and all of the formations were mapped as carefully as possible.

Acknowledgment is due the staff of the division of mines, Bureau of Science, for help rendered in symposiums concerning the various problems.

PREVIOUS WORK

Becker [1] in his report on the geology of the Philippine Islands gave a summary of all that has been done by geologists and scientists previous to this time, but it has no direct bearing on the Angat-Novaliches region. Becker's report, although written from limited observations, is an admirable paper on the geology of the Philippine Islands. His study of the rocks and his historical geology are interesting and in a general way affect the area under consideration. H. D. McCaskey [2] wrote a report on a geologic reconnaisance of the iron region of Angat, Bulacan. This region is just north of the Angat-Novaliches area. Adams [3] in his studies of the geology of southwestern Luzon touches lightly on the neighboring areas and briefly summarizes the geology. He produced a map showing the general trend of the limestone outcrops at Montalban; and shows both basalt and andesite east of Mariquina Valley. Dalburg and Pratt [4] also investigated the iron-ore region of Bulacan, and in their paper is given the best geologic data of the contigous region. They made a geologic map including Sibul and Norzagaray, and made an east-and-west cross section through Norzagaray. The portion of the present geologic map (Plate 2) north of Angat River is taken mainly from their map. H. B. Schenck [5] wrote a paper on the drainage control by jointing in Angat district, Bulacan Province.

The above are, more or less, general geologic reconnaisances, which, however, have served as fundamental bases for the unraveling of the local geology.

[1] U. S. Geol. Surv. 21st Ann. Rept. (1899–1900) pt. 3.
[2] Bull. Philip. Min. Bureau 3 (1903) pt. 2.
[3] Philip. Journ. Sci. § A 5 (1910) 57.
[4] Philip. Journ. Sci. § A 9 (1914) 201.
[5] Philip. Journ. Sci. 20 (1922) 57.

LOCATION AND EXTENT OF THE REGION

The region under discussion has an approximate area of 200 square kilometers and includes the region south of Angat River including Novaliches and a part of Mariquina Valley. Longitude of 121° east limits the area to the west and longitude 121° 10′ east limits it to the east. It lies in two provinces, and in-

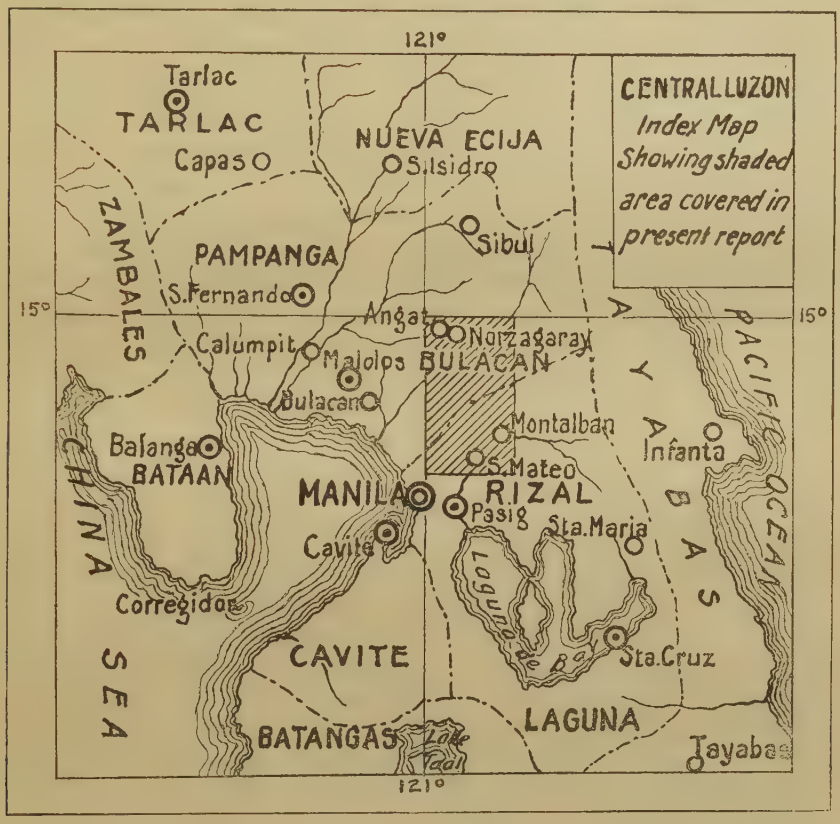

FIG. 1. Index map; the shading indicates the area covered by this report.

cludes the towns of Angat, Norzagaray, and San Jose del Monte, in Bulacan Province; and Montalban, San Mateo, and Novaliches in Rizal Province. (See index map, text fig. 1.)

CULTURE AND LIFE

The Angat-Novaliches region, while it is mountainous for the most part, is populated, though rather sparsely. The towns on the plains and in the low foothills are more thickly populated, and serve as supply stations and markets for those in the mountains.

Farming is the principal occupation on the plains. Sugar cane and rice are raised in the fertile Mariquina Valley. On account of the rolling topography in the foothills, rice paddies are absent, and varieties of rice which require no standing water are cultivated. A few big plantations have been noticed but as far as can be seen, very little is being done to develop them. All the desirable land in the neighboring mountains has been taken. Mountain rice, vegetables, bananas, and coconuts are grown wherever a suitable place can be found, and a few cattle are raised where grazing is good. The mountain people still make "caiñgins," or forest clearings, where they raise their staple foods, such as rice, camotes, and vegetables.

Lumbering is a popular occupation, especially among the people of Norzagaray, because Angat River with its swift current affords them a ready means of transporting their logs from the mountains to the town. Calantas, *Toona calantas* Merrill and Rolfe; ipil, *Intsia bijuga* (Colebrook) O. Kuntze; narra, *Pterocarpus blancoi* Merrill; and lanete, *Wrightia laniti* (Blanco) Merrill, are the principal forest products. Quarrying volcanic tuff for building stone is carried on in several places in Bulacan and Rizal. In San Jose del Monte a little placer mining is done, and cradles are used to recover the fine and coarse gold. Most of the inhabitants hunt and fish. In Angat River and its tributaries are some very palatable fishes.

Deer, wild hogs, and wild chickens inhabit the forests and the cogon-covered hills. "Alamid," or "musang" (*Viverra zibetha*) is common. Boas are said to be plentiful, especially in crags and rocky caverns. Small snakes abound, some of which, like the hooded cobra, are very poisonous.

Good roads connect all the towns to the provincial highways. From the towns, there are well-beaten trails leading into the mountains. Angat River, in spite of its dangerous rapids, is used as an avenue of transportation to Norzagaray.

In the higher mountains, there are some Negritos who seldom if ever go down to the towns. They are very peaceful and never bother anybody. Certain of the Tagalogs, called "remontados" and "taong gubat," or "mountain people," live independently in the inner recesses of the mountains. They are not as uncivilized as the Negritos, yet not as cultured as the other Tagalogs. They and the Negritos are mostly responsible for the caiñgins which are so harmful to the mountain vegetation. It is said that the taong gubat, or remontados, were refugees during the Philippine revolution, who made the mountain forests

their abode and have become so accustomed to them that they have made their permanent home there. They have intermingled with the Negritos to some extent, as may be seen from the Negrito traits easily discernible in some of the taong gubat.

However, the people usually met with in the mountains come from the towns and are of the civilized class. They work in the mountains and market their products in the towns.

The high mountains are thickly and heavily covered with forests. The dissected lava plateau is, for the greatest portion, covered with talahib, *Saccharum spontaneum* Linnæus, and small trees of which the alibangbang, *Bauhinia malabarica* Roxburg, is the commonest. Wherever there is limestone, there is almost always a rather thick growth of trees. Binayoyo, *Antidesma ghaesembilla* Gaertner; alibangbang, *Bauhinia malabarica* Roxburg; and duhat, *Eugenia cumini* (Linnæus) Druce, are the commonest trees; but others, as balete, *Ficus* sp., and mango, *Mangifera indica* Linnæus, can also be found. Boho, *Schizostachyum lumampao* (Blanco) Merrill, is plentiful everywhere, except in the high mountains. Very little "cauayan," *Bambusa spinosa* Roxburg, is found in the whole region.

PHYSIOGRAPHIC FEATURES

General.—The area under discussion forms a part of two great physiographic divisions of central Luzon. The southern and western low-lying tuffaceous portion is included in the Central Plain, and the eastern part, mostly mountains of extrusives and coarse intrusives, lies in the western flank of the Eastern Cordillera, which is composed of several high parallel ranges trending about north and south.

Relation of topography to lithology.—The region may be divided into five small areas which are underlaid by lithologically different formations and which have different mean altitudes above sea level. Though the geologic events of the past have been the fundamental factors in bringing about the difference in the mean altitudes of the five areas, the lithologic characteristics of the formations have also been influential, there being wide variations in their resistances to weathering and erosion. The division lines between these five areas, therefore, follow approximately the contact lines between the formations.

The low-lying plains.—Beginning from the southwest and west, the first topographic subdivision consists of the low-lying plains which are underlain by tuffs and tuffaceous sediments. The altitude above sea level varies between 35 and 85 meters. This is the eastern edge of the great Central Plain of Luzon.

The foothills.—The low-lying tuffaceous plains gradually merge into the foothills that form the second topographic subdivision. These foothills, ranging in elevation from 85 to 165 meters, are made up of tuffaceous sediments and alluvial material at the lower levels and conglomerates at the higher altitudes. They suggest a rolling topography of low rounded and flat hills with no special arrangement (Plate 6, fig. 1). Around Norzagaray, San Jose, and Novaliches, there may be noted elevated flats which are still preserved; two of them in particular are clear-cut and easily distinguished. One is at an approximate elevation of 85 meters, and the higher 135 meters more or less. After these two elevated flats had been noted, a general accordance of levels among the rounded hills was brought under observation and consideration. The highest flats are undissected remnants of plains of subaqueous deposition, uplifted from below shallow water, raised, and dissected, giving rise to the foothill topography. The higher hills and some of the lower hills of this subdivision are made up of fairly well-consolidated Pliocene conglomerates. At Lambak, from Angat River south to Santa Maria River where the upper Oligocene shales are present, the topographic expression is a depression because of the ease with which shales are eroded.

The dissected lava plateau.—The third subdivision is the dissected lava plateau underlaid by andesite and basalt, and some limestone. The elevation generally ranges from 165 to 350 meters, but east of Mariquina Valley it reaches about 430 meters. There is a marked accordance of levels among the flat or rounded summits as may be expected in a lava flow (Plate 5; Plate 8, fig. 1; and Plate 9, fig. 1). The average altitude of these flat summits or ridges is around 250 meters. West of Mount Lacotan there is a flat upland, with an area of about 4 square kilometers at an approximate altitude of 250 meters. This area has been slightly dissected and probably marks the approximate altitude of the top of the basalt flow, but as faulting and epeirogenic movements have occurred since its extrusion the present altitude is probably not the same as the original. Folding after the lava flow has resulted in higher peaks in some portions and lower in others.

There is no specific arrangement of the spurs and ridges in the lava area, because of the homogeneity of the rock and the fact that all of the rivers except the Angat have their sources here; consequently, the small tributaries have made an irregu-

lar dendritic pattern. In this area the drainage, with the exception of Angat River, is so young that jointing has not affected it noticeably. The result is a topography with a straggling pattern. The large limestone outcrops in the northwestern part of the region are included in this physiographic subdivision. These outcrops form prominent peaks and ridges, steep and craggy, towering above the surrounding country. In some places there are small isolated outcrops of limestone which generally protrude slightly above the lavas or have been exposed only by stream action.

The high ridges of limestone and the basalt mountains east of Mariquina Valley also belong here (Plate 5 and Plate 8, fig. 1). They are lithologically, structurally, historically, and genetically the same as those west of the valley, even though they have acquired a few of the characteristics of the topoghaphy of the high parallel ranges. The limestone outcrops tower above the surrounding country and have developed high peaks and steep slopes.

The Eastern Cordillera.—The fourth subdivision is the area of high parallel ranges made up of coarse-grained intrusive rocks (diorite, gabbro, peridotite, etc.) These coarse-grained rocks make up the next to the oldest formation known in the Philippines, the basal complex, which is the backbone of the Eastern Cordillera as well as of the big ranges of the Philippine Islands.

Mariquina Valley.—The fifth and last subdivision is the long, flat, straight valley occupied by Mariquina River, and known as Mariquina Valley. It is a graben, underlaid by recent alluvium, in fault contact with the low hills of tuff to the west, and the high basaltic mountains to the east. Structure, rather than lithology, has been the determining factor in the formation and development of this physiographic subdivision (Plate 2 and Plate 8, figs. 1 and 2).

RELATION OF TOPOGRAPHY TO STRUCTURE

The general monoclinal structure of the region may be detected from the general areal relations of the formations. The contact lines have a general north-south direction, except in the southern part where the contact lines swing around in a southeasterly direction following the low foothills and tuffaceous plains. The beds are younger to the west and older eastward into the mountains. They have a general monoclinal dip to the west, with minor undulations. This inclination is generally re-

flected in the abrupt eastern slopes of the ridges and more gradual western slopes. This relation, however, does not very well hold in the area which was covered by the lava flow.

Since a division into five physiographic portions has been made to show the relation between topography and lithology, these five portions will be taken up separately in discussing the influence of structure on the topography.

THE LOW-LYING PLAINS

The low-lying plains are of no interest in this discussion, since the tuffs and tuffaceous sediments are essentially horizontal and faults show no topographic expression, except, perhaps, in the general direction of the main rivers, or the abnormal course of a stream.

THE FOOTHILLS

The rounded foothills, underlaid by tuffaceous sediments and conglomerates which dip to the west, mark the beginning of the general monoclinal structure of the whole area. The conglomerates have a steeper dip than the younger sediments, sometimes reaching 13°. Because of this gentle western dip and the general westward slope of the whole area, there is a tendency for the western slopes of the hills to be flatter and gentler than the eastern slopes. In the foothills faulting has found some expression, but this is more obvious in the drainage pattern than in the peculiarities of the topography. Nevertheless, an unusual elongation of a hill has occasionally been observed along a fault trace. This area is separated from Mariquina Valley by a fault escarpment in tuff which abruptly terminates the rounded foothill topography (Plate 8, fig. 2). On account of the soft and easily eroded tuff, this escarpment is not well preserved.

In the Novaliches reservoir site, horizontal strata of water-laid tuff occupy the top of the flat hills, and there is a general accordance of levels at this altitude of about 135 meters above sea level. There is an absence of a general covering of alluvial material, except in the lower portions. These are uplifted terrains of pyroclastic material deposited and sorted under shallow water during the Pliocene when there were great volcanic explosions. These were uplifted in several stages, accompanied by slight folding and some conspicuous faulting. There are at least two stages of uplift recorded by two well-defined flat remnants, one about 85 meters and the other about 135 meters above sea level. Erosion has of course carved into these terrains the present topographic features.

THE DISSECTED LAVA PLATEAU

The dissected lava plateau with its undissected remnants is more fruitful in topographic expression of the local underlying structure. Here the andesite and basalt extrusions covered a region of limestone ridges which had already been folded, faulted, and eroded. After the lava flows, the region again suffered deformation. Due to the lava flood which covered this area, the dominant topographic feature is that of a dissected plateau with flat remnants and generally accordant summits, although erosion, folding, and faulting has somewhat couched its original structural simplicity.

In its upper course, Minoyan Creek follows a fault trace, sharply defined by a limestone escarpment which protrudes above the extrusives east of it and the sediments to the west as a long, narrow, prominent ridge covered with trees. Water gaps, underground rivers, and caves have been made in this limestone ridge by the creeks which cross it. Along Angat River, below Pared, there are high, steep, craggy peaks and ridges of limestone, bearing a luxuriant growth of trees, in marked contrast to the generally cogon-covered, rounded, or flattened hills of basalt and andesite. These prominent limestone outcrops were folded before the volcanic extrusions and acted as a barrier to the lava flows. The slopes of the limestone ridges are very steep; the eastern slopes oftentimes form cliffs due to the dip to the west and to vertical jointing. While the summits of the lava ridges and hills are flat or rounded, their sides are generally steep.

At Ke-Banban, there is a bowl-like depression of about 4 or 5 square kilometers. It is steeper on the northern side than on the southern side, and is hemmed in by ridges with only two narrow outlets, Ke-Banban Creek and Katitinga Creek. Since the structure can be deciphered only with difficulty in a lava-covered region, this depression, Ke-Banban Valley, has been tentatively ascribed to erosional processes, but because of its size and particularly its shape, it may have been greatly influenced by the underlying structure developed after the solidification of the lava.

East of Mariquina Valley, the basaltic mountains and the limestone ridges form part of the dissected lava plateau. In fact, this part of the plateau is nearer the source of the lava.

A prominent feature in this area is the steep, craggy, jagged ridges and high peaks of the elongated outcrop of Montalban limestone or Binangonan limestone, which stand out in sharp

contrast to the undulating skyline of the mountains of intrusives and extrusives (Plate 5). This limestone, especially at the Montalban dam where there is a gap, is badly fractured and fissured and perhaps has an almost vertical altitude, producing such prominent features (Plate 1 and 28). Extensive caves are present in the limestone at the dam, high above the present stream level. This limestone outcrop is elongated in a north-south direction in accordance with the general structure of the area.

The prominent peaks of this subdivision are Mount Salacot, 319 meters; Mount Bulak, 305 meters; Mount Osboy, 213 meters; Mount Pakiling, 220 meters; and Mount Tacbohan, 227 meters; the limestone peak on the southern bank of the Angat River at Pared, 305 meters; Mount Haponang Baboy, 480 meters; and Monut Pamitinan, 414 meters.

The Eastern Cordillera.—Ickis [6] crossed the Eastern Cordillera from Infanta, Tayabas, to Tanay, Rizal, and developed a cross section of the country he traversed. His reconnaisance was superficial and failed to show the relation of rocks of the basal complex to the overlying rocks. Adams [7] in his reconnaisance of southwestern Luzon, included a map, which, although incomplete as far as the Eastern Cordillera is concerned, gives an idea of its structure. It would seem, from the reports of the above geologists, that the Eastern Cordillera is a closely folded anticlinorium. The Angat-Novaliches region is on the western flank of this anticlinorium, and in this report is referred to as a monocline.

The axes of this anticlinorium and its auxiliary folds have a north-south direction and are parallel to the eastern coast line of Luzon. This is also the direction of the long axes of the intrusions and of the traces of the long principal faults. It is conceded that the main tectonic lines of Luzon in this vicinity lie in the same direction. The principal ranges of the Eastern Cordillera follow this general alignment, and it can be seen that the structure of this physiographic province has determined the carving of its present topographic features and characteristics.

The ranges of the Eastern Cordillera are fairly well aligned, and have steep slopes, probably due to the severe folding that the region has suffered and to the resistance of the rocks to weathering. Although there is no accordance of levels in the summits of the ridges, the skyline is not rough and jagged.

[6] Philip. Journ. Sci. § A 4 (1909) 483.
[7] Philip. Journ. Sci. § A 5 (1910) 57.

There are few towering prominences; a few peaks, according to Adams,[8] reach an altitude of about 1,400 meters (about 4,550 feet). In the area under discussion, the most prominent peaks are Mount Balabag, 798 meters high, and Mount Katitinga and Mount Lacotan, both 427 meters high. The bases of these peaks are elongated in a north-south direction following the general trend of the structure.

West of Mount Lacotan and Mount Katitinga, starting from the northwest corner of Mariquina Valley north to Ipo River, there is a long, marked, narrow depression, or trench, which is partly occupied by Pagup River (Plate 9, fig. 2). This trench is very conspicuous and can be followed easily. It is the northern continuation of fault 7 (Plate 2) on the western side of Mariquina Valley, and here marks the eastern limit of the dissected lava plateau.

MARIQUINA VALLEY

There is a strongly pronounced fault scarp in the western flank of the basaltic range on the eastern side of Mariquina Valley. This escarpment is very straight and well preserved and exhibits triangular facets at the end of its spurs, and here and there, faulted-off valleys (Plate 7, figs. 1 and 2; Plate 8, fig. 1).

Since there are fault scarps on both sides of Mariquina Valley, it is logical to assume that Mariquina Valley is a block which was faulted down, a graben. Its shape and direction and the relation to the structure and its unmistakable topographic features support this theory.

DRAINAGE

Drainage patterns frequently give one an idea of the structure of a region, but sometimes a region has to be studied well before the relation between drainage and structure can be understood. This is true of the Angat-Novaliches region.

The principal drainage system is Angat River with its tributaries. It has its source well up near the summits of the high ranges of the Eastern Cordillera and flows in a broken line, or zigzag, deeply incised in steep valleys and cañons in a general southerly direction, following the north-south alignment of topographic features and structure, until it strikes fault 2 (Plate 2) near the mouth of Ipo River. Then it assumes a general northwesterly course, not winding around, but, as in its upper

[8] Op. cit. 81.

course, zigzagging with sharp turns. It here follows the general direction of fault 2, which is probably the influencing element for its present lower course. The upper course of Angat River probably is controlled by a major fault, which may be a continuation of fault 7 (Plate 2), on the western side of Mariquina Valley. The abrupt turn of Ipo River, just north of Mount Katitinga and its course from there on, may also have been influenced by the same fault or by an auxiliary fault. The broken line, or zigzag character, of Angat River is an expression of the jointed structure of the rocks and also is probably due to small auxiliary faulting.

Angat River (Plate 9, fig. 1) is a very active stream, carrying a large volume of water at a fast rate, flowing over waterfalls in its upper courses and over rapids in its lower courses. It has cut a deep gorge, especially at Pared (Plate 6, fig. 2) where the stream is narrow and the banks high and almost perpendicular. It has only a few short tributaries from the west, but many more and longer tributaries from the east. Instead of being drained by shorter tributaries to the upper Angat River, the northernmost portion of the area is drained by long tributaries, such as Sapang Balete, Bayabas River, and Maasim River, which flow westward until they eventually find their way into the lower course of Angat River. From Ipo River to Norzagaray, its tributaries are merely small ravines. The positions of these tributaries further support the fact that the western slopes are much gentler than the abrupt eastern slopes, and since this is a reflection of the regional monoclinal structure, the relation between the drainage pattern and the structure is evident.

Santa Maria River and Sapang Alat are the two rivers south of Angat River which have general westerly directions. Santa Maria River seems to follow the direction of fault 3 (Plate 2), just as Angat River follows fault 2. Minoyan Creek, Osboy Creek, Biniakdan Creek, Katitinga Creek, and Ke-Banban Creek are all tributaries of Santa Maria River. These tributaries have their sources in the dissected lava plateau and drain most of it. The streams and creeks have general westerly directions, although the pattern has no particular arrangement. Sapang Alat with its tributaries drains the southern part of the lava area. Santa Maria River and Sapang Alat do not flow into Angat River, but empty into Bulacan River, one of the distributaries in the great Pampanga River delta.

Minoyan Creek, a tributary of Santa Maria River, follows fault 1 (Plate 2) a short distance, along a limestone escarpment.

The southern portion of the whole area is drained by Novaliches River, which flows southward and southwestward. This river and some of its tributaries show the influence of faulting, as may readily be seen from the accompanying map (text fig. 2).

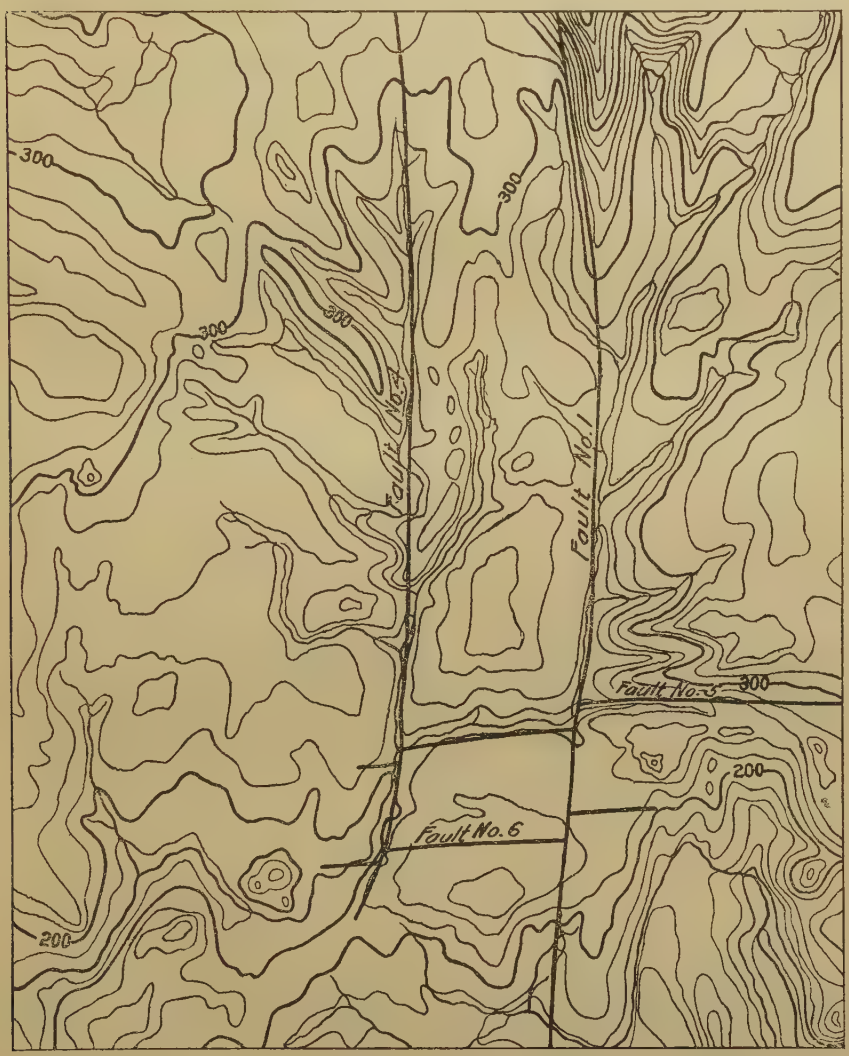

FIG. 2. Faulting at Novaliches River.

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The first remarkable feature is the angularity of the pattern; Camates Creek and Novaliches River are almost parallel in this vicinity. Then Novaliches River makes a right angle turn and meets Camates Creek. Since the formation here is tuff and tuffaceous sediments with only a small inclination, it cannot be that rock structure has had any influence in the development of this pattern. This system of faulting will be discussed more fully under structure.

The Mariquina River system has many tributaries in its mountainous watershed and their sources are well up in the ranges of the Eastern Cordillera. While the general trend of the system is westward, cutting through the ranges, most of the tributaries are parallel or subparallel to the structural lines of the Eastern Cordillera. It has cut a remarkable gap in the limestone at the Montalban dam. This river, or its predecessors, is probably responsible for the caves in the limestones at the dam. Stream pebbles are common in the caves. Mariquina River, after it passes the mountains, reaches the flat Mariquina Valley, strikes fault 7, and makes a sharp turn to the south where the stream meanders on an alluvial plain in the graben. Fault 7 with its low escarpment of tuff has limited its meanderings and side cutting to the west. In the valley there are several long tributaries from the east, but few and short ones from the west. The area just west of Mariquina Valley is drained mostly by the Novaliches River system and the San Juan River system.

Wawa Creek is a north-flowing branch of Mariquina River joining it near the office of the Montalban reservoir. It has followed a very sharp anticline in the shales of the Batan formation. It is also probable that a fault marks the western side of this valley. This valley is remarkable in that a low limestone ridge running through the center looks as if it had slidden down from the western slope.

GEOLOGICAL FORMATIONS

GENERALIZED SECTION

Cenozoic.

Quaternary.

Recent alluvium; 0 to 20 meters; maximum altitude 65 meters.

Pleistocene alluvium; 0 to 35 meters at elevations between 65 and 150 meters.

Tertiary.

Pliocene.

Guadalupe tuff; 150 meters at least, in the area.

Alat conglomerates; 35 meters ±.

Miocene.
Mariveles andesite; 65 meters maximum.
Antipolo basalt.
Basalt; 350 meters maximum.
Basalt; "Volglomerate"[9] 20 meters ±.
Oligocene.
Lambak shales and sandstones; 100 meters ±.
(Vigo formation.)
Binangonan limestone; 20 to 200 meters ±.
Batan formation; 100 to 500 meters ±.
(Coal Measures.)
Eocene.
None observed, probably absent.
Pre-Tertiary.
Mesozoic.
Post Jurassic or Cretaceous.
Pyroxenites, peridotites, serpentines.
Jurassic?
Radiolarian cherts?
Triassic?
Paleozoic.
Permian.
Basement complex: Diorites, gabbros, etc.
Pre-Permian.
Granite and granodiorite.

PRE-TERTIARY

THE PRE-PERMIAN ROCKS

In the area included in this paper, the outcrops of granite and granodiorite are very small, and the conclusions were drawn from the extensive outcrop of granite just north of the present area. This granite is believed to be the oldest rock in the region, even older than the "basement complex" which forms the backbone of the Cordilleras.

Granite.—At Sapang Caliñgao, two specimens of granite were collected by Pratt and Dalburg, one of them at the diorite contact.

The specimen collected far from the contact is a light-colored, medium to coarse-grained rock. Its texture under the microscope is hypautomorphic coarse inequigranular, the feldspar sometimes being automorphic. The essential minerals are quartz, orthoclase, and some plagioclase with hornblende, hem-

[9] "Volglomerate" is a term proposed for a lava flow which has included in it much alluvial material of heterogeneous composition. Agglomerate is a chaotic assemblage of coarse angular pyroclastic materials of a more or less homogeneous composition.

atite, zircon, and apatite as accessory minerals. Most of the hornblende has altered to pistacite (epidote), chlorite, and iron oxide. The feldspars are greatly weathered and are altered to kaolin, pistacite, and chlorite. The granite is very greatly altered.

The specimen at the diorite contact is a light greenish-gray, dense, crystalline rock, jointed and cleaved. Under the microscope its texture is fine, granular, sutured, with occasional xenomorphic orthoclase phenocrysts. The essential minerals are quartz and orthoclase with magnetite, apetite, and zircon as accessories. The secondary minerals are pistacite, zoisite, chlorite, iron oxide, kaolin, and opacite. Grossular garnet occurs to the intrusion of diorite. The specimen is full of fissures lined with secondary quartz and limonite. Dalburg and Pratt, who collected this specimen, observed its occurrence at the contact with diorite. It is, therefore, a metamorphosed facies of the old granitic stock. Weathering is far advanced, and the original ferro-magnesian minerals have all been altered to chlorite, pistacite, and iron oxide. The feldspar is also weathered to kaolin, chlorite, and pistacite. The diorite was probably intruded along the border of the granite stock, because the texture of this specimen and its composition seem to point to a border or contact facies.

At Santol, Smith collected a specimen of granite and marked it, "Diorite, near granite contact." Megascopically it is fine greenish-gray granular rock with pyrite disseminations. Under the microscope the texture is inequigranular microcrystalline, hypautomorphic porphyritic, intruded by a hyaline microlitic omniversal to trachytic rock probably an andesitic equivalent of the old diorites. The mineral composition of this granite is much the same as the other specimens. It is clear, from its contact relation, that it had been intruded by the same magma which gave rise to the diorite.

The granite is greatly altered and weathered. Sometimes the ferromagnesian minerals have been altered and the feldspar is almost beyond recognition. The basic rocks, while they are somewhat altered and weathered, are still comparatively fresh.

The evidence points to an older age of the granite intrusion, and it is probably the oldest rock known in the Philippine Islands. It indicates, therefore, that the oldest rocks were acidic. However, not all granites of the Philippines are of this age. There are younger granites in other localities, as the Paracale district, where granite was intruded into Tertiary sediments.

Rhyolite.—Schenck collected a specimen of an acid extrusive at Pared, Angat River. Megascopically it is a weathered, greenish dark-gray, fine, crystalline, calcareous rock with pyrite grains. Under the microscope its texture is sutured, microcrystalline hyalopilitic, and somewhat microlitic. The essential minerals are orthoclase and quartz; with hornblede, apatite, zircon, topaz, magnetitte, pyrite, and chloritic glass as accessories. The secondary minerals are pistacite, chlorite, calcite, iron oxide, and kaolin. Due to the accessory and secondary minerals the rock is dark. It is probable that the rock is an altered rhyolitic lava. Rhyolite has also been noticed in alluvium in Bocaue, brought down by Santa Maria River. This rock is probably an extrusive phase of the old granites, which outcrop farther north.

Granodiorite.—A specimen of granodiorite was collected by Schenck in Sapang Paila, a branch of Angat River near Paila. It is light colored and coarse granular, with magnetite and pyrite disseminations. Megascopically, it looks like granite. Under the microscope the texture is hypautomorphic granular with intersertal subrounded quartz grains. The essential minerals are andesine, quartz, and just enough orthoclase to make it a granodiorite. Magnetite, hornblende, pyrite, zircon, and apatite occur as accessory minerals with kaolin, chlorite, and limonite as secondary minerals. This rock may belong to the same age as the granite, since it is more acid than the rocks of the basement complex.

THE BASEMENT COMPLEX OF PROBABLE PERMIAN AGE

In spite of the greater age of the granite, the present writer, besides conforming to an established term, persists in assigning the term "Basement Complex" to the basic igneous rocks, which largely make up the cores of the Philippine cordilleras, because the granite outcrops are probably only small local lacolithic or stock intrusions.

THE PLUTONIC IGNEOUS ROCKS OF THE BASEMENT COMPLEX

Hornblende gabbro.—This specimen is a piece from a bowlder float at the mouth of Ipo River. There are many of these bowlders and on account of their sizes which reach several feet in diameter, it is clear that their source could not have been far, although Angat River and its branches are powerful during the rainy season. The rock is dark, coarse-granular with large feldspar and hornblende crystals. In some bowlders there is a sharp conspicuous band in which the minerals are much larger.

This band is not intrusive into the mass. Under the microscope the rock is very coarse-granular hypautomorphic, and in places ophitic. It should be stated that ophitic hornblende gabbro is common. The feldspar is labradorite. Hornblende is the dark mineral; magnetite also occurs. The secondary minerals are chlorite, kaolin, and talc.

Diorite.—Diorite is another common rock in the mountain cores. Since it is the rock most commonly in contact with the older and younger rocks of the basement complex, it was probably intruded before the gabbro, which seems to occupy the central part of the mountain cores. Samples of diorite were collected along Ipo River near the contact with the Miocene lavas. There is also diorite float in Angat River and Ipo River. Megascopically, this diorite is a fine-granular, dark rock with occasional small plagioclase phenocrysts. Under the microscope the texture is allotriomorphic granular to ophitic. Hornblende predominates over the plageoclase, which in this case is oligoclase-andesine. Magnetite disseminations are frequent. Fine-grained diorite is very common. At Marapo River, Matulid, Angat, Pratt and Dalburg collected a very fine-grained diorite of almost the same composition as the above. The hornblende is seen altering to epidote, chlorite, and iron oxide. It has been observed that pistacite, or epidote, is a common alteration mineral in the igneous rocks of Bulacan.

Dacite.—This specimen was collected by Schenck at Paila, Angat River. It is a fine-grained, greenish-gray rock with parallel elongated cavities which are probably due to an application of pressure after the rock full of rounded gas pores had solidified. These cavities have been filled with the yellowish-green pistacite. Under the microscope the texture is automorphic porphyritic microcrystalline, or microlitic subparallel to diverse. In places there is a subparallelism of the microlites to the elongated cavities. The entire rock is somewhat hyaline. The minerals are phenocrysts and tiny laths of plagioclase, irregular grains of quartz, magnetite, apatite, pistacite, chlorite, iron oxide, and kaolin.

Dacite porphyry has also been found north of the present area, at Talagio River and Maon Creek, by Dalburg and Pratt. in the Camachin iron-ore deposits syenodiorite has also been collected.

BASEMENT COMPLEX DIKE ROCKS

At Pared, near Paila, on Angat River, there is a small locality of basement complex rocks with acidic and semiacidic dike

rocks (Plate 11, fig. 1, and Plate 14, fig. 1). A dacitic dike rock at Pared is dark gray and dense, with epidote in the cavities. Under the microscope the texture is fine-granular, hyaline-crystalline, with felty to subaparrallel laths of andesine and some granular quartz. The cavities are filled with epidote and secondary mosaic quartz. There are many quadratic sections of magnetite. Zoisite, glass, chlorite, kaolin, and iron oxide are present. The magnetite and the chlorite make the rock appear dark. Another dacitic dike rock is bluish gray and dense. Under the microscope it is cryptocrystalline granular with a microlite groundmass. In places it is automorphic porphyritic. There is also a subparallel arrangement of microlites and feldspar laths. The phenocrysts are andesine. Granular quartz and orthoclase occur with laths and microlites of andesine. Hornblende magnetite, chlorite, kaolin, and iron oxide also occur. This dike was found close to quartzitic dike rock.

The quartzitic dike rock is composed of a white dense rock. Under the microscope it is fine cryptocrystalline almost equigranular; mostly quartz, a little orthoclase, zircon, kaolin, limonite, and epidote. These dikes are probably the last to be intruded. Since there are many dacitic dike rocks, it is probable that dacite was one of the last products of the intrusion of the rocks of the basement complex. These dike rocks are in anorthosite and other old fine-grained extrusives.

EXTRUSIVES OF THE BASEMENT COMPLEX

Anorthosite extrusive.—This specimen (Plate 20, fig. 1) was collected at Batong Anay, Angat River, under the Binangonan Oligocene limestone. It is a dense black rock with submetallic luster. Under the microscope its texture is irregular, haphazard, finely crystalline to hypautomorphic porphyritic with a groundmass of xenomorphic orthoclase and hypautomorphic elongated laths of plagioclase. The minerals are labradorite phenocrysts, granular orthoclase, magnetite in great amounts giving a dark color and a metallic luster to the rock, glass, iron oxide, sericite, and kaolin. No ferromagnesian minerals were observed, and neither were there any secondary minerals derived from them. The Miocene lavas with which it may be confused have a different texture and composition and contain much hornblende. This rock is a Pre-Tertiary anorthosite, and this opinion is based on its position under the Oligocene limestone. The limestone at the contact is not metamorphosed; therefore, this anorthosite cannot be Post-Oligocene.

THE BARUYEN CHERTS

Cherts of probable Jurassic age.—The outcrop of these cherts (Plate 20, fig. 2; Plate 21, fig. 1) are rare, small, and isolated. They have been reported from this region by former geologists. At Ipo River, about 5 kilometers from its mouth, there is an outcrop about 35 meters long and about 15 meters high. The chert is very hard and dense, and emits a ringing metallic sound when struck with a hammer. It is evenly stratified; the beds are about 2.5 centimeters thick. The beds are reddish brown or bottlegreen, and one color or the other generally persists in each bed. The strata are tilted and strike north 13° east and dip 60° west.

Under the microscope it is seen that the red chert, or jasper, is coarser and contains hematite which gives it the brownish-red color. Included in it are many angular grains of feldspar, mostly plagioclase, and some quartz, and their clastic nature can be easily distinguished. These clastic grains are embedded in the hematitic and opacitic semicrystalline or chalcedonic silica.

The green chert owes its color either to chlorite or to glauconite; it is fine microcrystalline chalcedonic silica, and clastic grains are very rare. No radiolarians were noticed in the green cherts, but radiolarian tests were observed in the red chert (Plate 20, fig. 2). Smith has published pictures of radiolarians from the red cherts of Ilocos Norte, called the Baruyen formation,[10] which probably belong to the same age and formation as the Bulacan cherts. These cherts may also be correlated with the cherts of the Danau formation of Molengraaff [11] in Borneo. Martin[12] found similar cherts in a more or less similar stratigraphic position in the Moluccas.

The age of the Baruyen cherts is probably Jurassic.[13] Molengraaff also gives this age to the cherts of Borneo. Since the fragments of feldspar are mostly plagioclase, it is probable that these cherts were laid down after the intrusion of the basic igneous rocks of the basement complex. Furthermore, these cherts are generally found on the flanks of the high cordilleras. The cherts have not been intruded by the basic igneous rocks, and

[10] Geology and Mineral Resources of the Philippine Islands, Manila, Bu. Sci. Publ. 19 (1925) 11–74.

[11] Geological Exploration in Central Borneo. Leyden (1902) 414–415.

[12] Reisen in den Molukken, Geol. Teil. Leyden (1902) 164.

[13] Smith, op. cit. 71.

are generally found in areas which have been covered by the Miocene lavas or by the Oligocene limestone.

According to Molengraaff these radiolarian cherts are probably deep-sea deposits on account of the fineness of the sediments, their uniformity, and the presence of radiolarian tests.

CRETACEOUS ULTRA-BASIC INTRUSION

Augitite.—A sample of augitite (Plate 21, fig. 2) collected on Ipo River (see map, locality 5) is megascopically a dark-green, granular rock with dark phenocrysts. Under the microscope it is hypautomorphic porphyritic with a hypocrystalline to vitrophyric opacitic groundmass. Its minerals are mainly augitite, some plagioclase, a little hornblende, glass, and chlorite. This is an extrusive or hypabyssal rock, probably a differentiation facies of the intrusion of pyroxenites, peridotites, and serpentines, which came after the cherts were deposited and which are found throughout the Archipelago. Pratt and Dalburg also collected a sample of augitite in the Camaching iron-ore deposits with some secondary quartz. These rocks have been observed intrusive into Baruyen cherts in other localities, and probably are Cretaceous.

TERTIARY

OLIGOCENE

Batan formation (Coal Measures).[14]—On account of the lava flows, there are few and very poor exposures of the lower Oligocene sediments, called the Batan formation beneath the Binangonan limestone which is also Oligocene. Heretofore, writers have given the Binangonan limestone and the sediments below it a Miocene age, but it is here assigned to the Oligocene on the strength of geophysical evidence. Moreover, recent faunal and stratigraphic studies tend to determine the Oligocene age of these formations.

At Baraka, on Angat River, black shales were encountered under the Binangonan limestone and under these a conglomerate (Plate 13, fig. 2). At Bicti, probably beneath the limestone, a small outcrop of fine, well-rounded conglomerate was noticed, somewhat sandy and disintegrating. These are the only exposures of the basal Oligocene conglomerate brought under observation, and they are far from satisfactory. Pratt and Dalburg [15]

[14] Dalburg and Pratt, Philip. Journ. Sci. § A 9 (1914) 213, call this Miocene.

[15] Philip. Journ. Sci. § A 9 (1914) 213.

found along Bayabas River, a little distance to the north of the present area, under the Binangonan limestone, shale, tuffaceous sandstone, quartz sandstone, and conglomerate. Pratt and Dalburg assign them to basal Miocene, since the conglomerate is found immediately above the granite and older effusives. In Santol Creek they found the same relations, and also noted a white crystalline marble close to the bottom of the series. The thin, white, crystalline limestone at Bakas may be the corresponding limestone in the present area, since it appears as to be below the black shales nearby. It contains the same Foraminifera or *Lepidocyclina* as the Binangonan limestone (Plate 26, fig. 2). These sediments, consisting of conglomerate, limestone, and shales, are probably not thick along Angat River.

At Montalban Gorge, on the northern bank, there is an outcrop about 200 meters long of the Batan formation, striking north 24° east and dipping from 60° to 70° east (Plate 18, fig. 1). The exposed strata are at least 150 meters thick. Farther downstream the outcrops are covered, but the limestone on top shows clearly that this is the crest of a sharp anticline. There are thick exposures of these shales and sandstones along Wawa Creek which flows from the south joining the main river a little distance downstream. Here the thickness of the Batan shales may exceed 500 meters.

The sediments are for the greater part dark hardened shales with beds of fine dark sandstone, and here and there a thin limestone layer. No coal was found at Mariquina River, but along Puray River, in the northern extention of these outcrops, and in the upper Wawa Creek, coal has been observed. It may be said, in passing, that most of the coal in the Philippines is found in this formation.

Binangonan limestone.[16]—The Binangonan limestone, of middle Oligocene age, is a gray to white crystalline fossiliferous limestone which has been metamorphosed both by dynamic movements and by the Miocene extrusives. It is badly broken up and jointed, its attitude being determinable only in a few places. In general, the strike is between north 13° east and north 30° east and usually dips west from 13° to nearly vertical except where it is folded into an anticline. Solution cavities and caves abound in this limestone, among which are the caves at Montalban Gorge (Plate 17; Plate 18, fig. 2), Suclib Cave (Plate 12, fig.

[16] Geology and Mineral Resources of the Philippine Islands, Bu. Sci. Publ. 19 (1925) 310; and G. I. Adams, Philip. Journ. Sci. § A 5 (1910) 79–84.

1) on Angat River, and the caves at Bicti. An underground river flows into Angat River at Kay Basa rapids (Plate 12, fig. 2).

There are some extensive outcrops of this limestone. It is very conspicuous below Pared on Angat River, along Minoyan Creek down to Santa Maria River (Plate 10), and in the Montalban Gorge district where it makes high peaks and ridges. There are also many small isolated outcrops throughout the area which fall in two lines trending north 13° east. The significance of this will be discussed under Structure. Suffice it to say that the Binangonan limestone and older formations were covered by the Miocene lava flows except in their higher portions where previous folding and faulting had pushed them up causing their outcrops to be irregular in distribution.

Naturally, the lava flows metamorphosed the limestone, but the absence of contact metamorphic minerals is surprising. At Katitinga Creek about 1 kilometer north of Ke-Banban, the limestone is in contact with both basalt and andesite, it is dark gray and is full of dark specks, mostly magnetite. Under the microscope it is seen that the andesite and the limestone have mixed together so that at the contact the rock is calcareous but it has a decided andesitic texture (Plate 24, fig. 2; Plate 25, figs. 1 and 2). A little farther from the contact, the limestone includes many grains of feldspar, some hornblende, and magnetite. No typical contact minerals were found. It is clear that the hot andesite fused and absorbed much limestone when the lavas were extruded producing the mixture just described. A little distance away from the contact there was much less fusion.

The fossils found in this limestone are mostly corals and lepidocyclinas which Faustino has ascribed to the Oligocene age. The physical history of the region strongly supports the Oligocene age of the Binangonan limestone and its associated formations. On account of close folding and faulting, and the fact that the lava flow has concealed much of its structure, its thickness could not be accurately measured. In places it may be only about 20 meters thick; while in others, as at Montalban, it is probably 200 meters or more.

Lambak shales and sandstones (*probably equivalent to the Vigo formation*).[17]—West of the outcrop of Binangonan limestone at Minoyan Creek there is a long comparatively narrow depression occupied by shales and sandstones, which are some-

[17] W. D. Smith, op. cit. 78 and 80; and G. I. Adams, op cit. 79–84.

what tuffaceous in places. This series of sediments is conformable on the Binangonan limestone and is about 100 meters thick. Since the above depression is called Lambak, this series has been designated as the Lambak shales and sandstones, and is of upper Oligocene age. It consists mostly of moderately hard, somewhat cherty, greenish-blue shales, greatly laminated, jointed, and folded. There is a tendency towards concentric lamination suggesting concretionary structure. There are a few layers of medium-coarse, light-colored sandstone which is somewhat tuffaceous.

This formation is undoubtedly wide-spread over the area, but erosion has worn it from the ridges, and the former depressions where they were undoubtedly present, have been covered by the lava flows. In Lambak it was not reached by the lava flows, on account of the protection afforded by the limestone escarpment along Minoyan Creek.

This formation has been described from the area farther north by Dalburg and Pratt,[18] but it is probably much thicker there. They assigned it to the Upper Miocene, but in the present paper it has been assigned to the Oligocene, being conformable on the Binangonan limestone.

MIOCENE

The Miocene lava flows.—The Miocene in this area is represented wholly by lava flows which probably emanated from the region around Antipolo, Rizal. On an eroded topography of greatly disturbed Oligocene and older rocks, basaltic lava flows probably overran the region, during the middle Miocene.

Volglomerate.—The oldest flow or the lower part of the basaltic flow is conspicuous for the great amount of included alluvial material of heterogeneous composition, produced by the Lower Miocene erosion. Because of its heterogeneity this is not truly a volcanic agglomerate and the term, "volglomerate" has been proposed for it. Most of the included pebbles are clearly alluvial, because well-rounded pebbles are common. Good outcrops of this volglomerate (Plate 11, fig. 2) may be seen along Ipo River and Angat River. These pebbles are mostly diorites, gabbros, and old extrusives. The matrix of the basaltic volglomerate is somewhat mottled in appearance. Under the microscope it has a glassy fluidal texture, enveloping, as it were, crystalline particles (Plate 23, fig. 2). The glass is yellowish green to green, due to iron oxide and chorite.

[18] Philip. Journ. Sci. § A 9 (1914) 212.

Elongate cavities are common. The volglomerate itself is thin, probably not exceeding 20 meters.

The Antipolo basalt.—Immediately above the volglomerate is the basalt proper (Plate 22, fig. 1). It is a dark, fine, crystalline rock, sometimes very dense. Under the microscope it is automorphic porphyritic with a groundmass of glass, or microlites, or both. Phenocrysts are labradorite and sometimes small crystals of hornblende. It contains characteristic magnetite in flaky disseminations. Chlorite, hematite, kaolin, limonite, and opacite are found as secondary minerals. The basalt varies in texture in different localities, but the component minerals are the same. It is about 200 meters thick, and covers most of the area under consideration but does not extend west of Minoyan Creek. The map (Plate 2) shows the areal relations.

Basalt obsidian or variolite (Plate 22, fig. 2; Plate 23, fig. 1).—At Ipo River, about 4 kilometers from its mouth, a dark-greenish rock with white phenocrysts and a suggestion of flow structure or semischistosity, which may be due to flow or to pressure, was encountered. Under the microscope it is porphyritic automorphic, with a groundmass that is hyalinocrystalline felty to parallel laths, with spherulites, axiolites, and lithophysæ made up of delessite (chlorite). The axiolites are parallel to each other. The minerals are orthoclase, labradorite, quartz magnetite, delessite, chlorite, kaolin, calcite, iron oxide, and topaz. Some places show evidence of a later injection of the same magma into the then hardly solidified magma. This is a basic, glassy, extrusive rock with some orthoclase phenocrysts and smaller crystals of labradorite. It may be termed basalt obsidian or variolite. This rock has some similarity in texture and composition to the matrix of the volglomerate.

Tachylite (Plate 23, fig. 2).—A sample of float from the mouth of Ipo River is a porphyritic or an agglomeratic basalt glass, probably a tachylite. It is a dark-mottled dense agglomeratic rock. Under the microscope the texture is hyalinocrystalline automorphic porphyritic. The groundmass is dark and glassy with microlites and automorphic tabular crystals. The minerals are labrodorite phenocrysts and microlites, glass, magnetite, secondary quartz, hematite, chlorite, calcite, kaolin, and talc. Some cavities are concentrically filled with calcite, chlorite, and cryptocrystalline quartz.

The Mariveles andesite (Plate 24, fig. 1).—This andesite is referred to as the Mariveles andesite since it is the formational name in the Philippines for the Upper Miocene andesite flows.

This andesite lies on top of the basalt flows. Its appearance and texture varies in different localities. Near Minoyan Creek at Butarero it is very badly weathered. At Katitinga Creek near Ke-Banban it is coarse porphyritic with hornblende phenocrysts, and one mile west of there it is much coarser and darker. At Mount Capitan Pascual it is medium coarse and the dark phenocrysts are small. Under the microscope, the texture is automorphic to hypautomorphic porphyritic with a glassy to cryptocrystalline dark groundmass. The feldspar is oligoclase to oligoclase-andesine. Hornblende is very common; hypersthene and augite, rare. Some biotite may have been derived from the hornblende. Magnitite is very conspicuous, as in the basalt. The andesite occupies the western edge of the Miocene lava area. It is about 65 meters thick, but it was probably more extensive than it is now, as denudation must have worn off a great portion of it. No indication as to its source has been found in the area. It also seems that the andesite flow did not cover the higher elevations of basalt and only flanked it on the lower altitudes to the west. Andesite elevations do not exceed 200 meters above sea level, a fact which indicates that the fissure or vent for the andesite was lower than the source of the basalt. Adams [19] reported andesite associated with the basalt east of Mariquina Valley. Ickis [20] in his cross section from Infanta to Tanay also encountered andesites. Whether these andesites belong to the same flow, or are merely contemporaneous, is not known.

PLIOCENE

In a shallow sea that occupied the central plains the Pliocene sediments and volcanic ejectamenta were deposited on a sinking bottom. There are two members; namely, the Alat conglomerate and the Guadalupe formation which is mostly tuff.

The Alat conglomerate (*Plate 14, fig. 2*).—This formation is at the base of the Pliocene and marks the unconformity on the Miocene lavas. The type section is in Sapang Alat where it strikes about due north and dips as much as 13° downstream to the west; in places it is gently folded. It is a marine littoral conglomerate and its eastern extent marks more or less the boundary of the Pliocene sea at its greatest extent. The conglomerate itself is well cemented and the pebbles reach 45.72 centimeters in diameter, but the average size is about 1.3 centi-

[19] Philip. Journ. Sci. § A 5 (1910) 77.
[20] Philip. Journ. Sci. § A 4 (1909) 483–489.

meters. The material is well sorted, and the stratification is well defined. There are local unconformities and cross beddings. A few thin layers of sandstone, sometimes tuffaceous, and some greenish olive drab shales are interbedded with the conglomerate beds, which are about 35 meters thick. The pebbles are composed of all kinds of rocks—diorite, gabbro, basalt, andesite, limestone, etc. Many of the limestone pebbles have been partially or entirely dissolved out of the matrix which is gray, calcareous, coarse, semiangular to subrounded, inequigranular, and with tiny pebbles.

The Guadalupe tuff formation.—The Guadalupe tuff formation is a thick series of well-stratified andesitic tuff and tuffaceous sandstones, shales, and conglomerate, found in the western and southern portion of the area at the edge of the Central Plain. The beds are generally between 30 centimeters and 1.5 meters thick. In this area, the total thickness is probably only about 150 meters, but to the west and south, the beds are thicker. Artesian-well records show that they are very thick. The strata are generally horizontal, but near the foothills they dip to the west, partly due to the original deposition on a slope. Gentle folding in the Alat conglomerates shows that slight compressive movements have taken place after the Pliocene. Near Norzagaray the tuff is gently folded. Fossil wood and fossil leaves have been found in the Novaliches reservoir dam site. Locally it is very conglomeratic on account of former streams which deposited coarse material in times of torrential downpours and floods.

QUATERNARY

Pleistocene gravels.—The Pliocene volcanic ejectamenta probably almost filled the Pliocene interior sea which occupied the central plains. At the close of the Pliocene, there was a period of general diastrophism which initiated the emergence or the uplift of the region resulting in the present elevation.

The elevation since the beginning of the Pleistocene must have amounted to about 165 meters, because this is the highest elevation where Alat conglomerate has been observed. However, gentle Post-Pliocene folding and faulting may have slightly elevated the conglomerate.

The highest Pleistocene terrestrial gravels were observed near Norzagaray, immediately west of Lambak at an approximate elevation of 135 meters. Pleistocene gravels generally occur as thin mantles, and sometimes as accumulations in depressions.

The next general accordant elevation of Pleistocene gravels is at about 85 meters. Around Novaliches, it is probable that the accordance of levels at an average height of 135 meters, with flat-topped ridges, is due to the original deposition of the tuff under water. Since this portion is nearer to the sea at present, it must still have been under water when the portion around Norzagaray was already land on which terrestrial gravels were accumulating.

Fossils are lacking and the division between Pleistocene gravels and recent alluvium is not sharp. The altitude of about 135 meters has been taken as a division line, because the highest gravels which clearly belong to the most recent river deposits do not exceed that altitude.

Recent alluvium.—This is found along the alluvial plains and flood plains of the present river systems, especially Angat River and Mariquina River. It is probably about 20 meters thick, and may be considerably more in many places. The barrio of Matictic is built on an alluvial flood plain which is constantly being destroyed on its eastern side by the lateral cutting of Angat River. This alluvium is made up of all kinds of river gravel with occasional lenses of sand and clay. During earlier erosion and deposition, much of the recent gravels and the Pleistocene gravels as well, at their margins near the mountains, were no doubt overlapping alluvial fans.

STRUCTURAL GEOLOGY

General.—The area under consideration is on the western flank of the Eastern Cordillera and on the eastern edge of the great central plains. The Eastern Cordillera is an anticlinorium with several intrusions of basic igneous rocks for its core. It is made up of three parallel ranges with a general north-south trend, parallel to the direction of the major tectonic lines of Luzon. The intrusions, therefore, are elongated north and south forming the backbones or cores of the Cordillera. The major structural and physiographic features are in keeping with the general tectonics of the region.

In the Angat region, the formation has a general dip to the west, although there are minor folds in the anticlinorium. This western dip is reflected in the gentler western slopes and steeper eastern slopes of the ridges and in the long westward and short eastward flowing tributaries of the river systems.

The greater part of the area was covered by the flood of Miocene lavas, thus concealing from observation many of the structural features and details of Pre-Miocene geology. This

lava plateau has been dissected, but it is still recognizable from the flat-topped hills and ridges bearing a general accordance of summits. In fact some geologists, on first seeing the region, have noted that this accordance of summits suggested peneplanation. This dissected lava plateau is now gently folded, and several faults cross it.

NOTES ON PRE-LAVA-FLOW TOPOGRAPHY AND STRUCTURE

The cherts on Ipo River about 5 kilometers from its mouth are exceedingly well stratified and the attitude was accurately determined. The strike was north 13° east and the dip 66° west. The fissured and broken-up character and the massiveness of the limestone made it difficult to determine the attitudes in different localities. At the mouth of Ipo River the probable strike is north 15° east, with a very steep dip to the west. Along the upper Angat River near Sapang Puti (locality 10) the probable strike is about north 15° east, and the dip was questionable. Among the isolated limestone outcrops surrounded by Miocene lavas, there seems to be a persistent strike of north 15° east, and a general persistent dip to the west to nearly vertical. At Montalban Gorge, the basal shales and sandstones strike north 24° east and dip 60° to 70° east on the eastern limb of the sharp anticline there. A study of the region around Montalban by Adams [21] also shows the same general attitude. Ickis,[22] crossing from Infanta to Tanay, also found the limestone sharply folded with axes about due north-south. The limestone outcrops east of Montalban follow these folds. It is evident that the cherts and the Oligocene sediments have a similarity of attitudes.

All the isolated limestone outcrops in the area fall in two more or less straight lines, trending between north 10° east to north 15° east. These limestone outcrops are the high elevations which were not covered by the Miocene lavas, although some of the outcrops were exposed only by stream cutting. Limestone, therefore, was the predominant material of the ridges in the Pre-Miocene topography just as the same limestone makes prominent ridges at present in Montalban and in the area east of Sibul, San Miguel, Bulacan. It seems, therefore, that in the pre-lava-flow topography there were clear-cut, regular, straight ridges which trended between north-south to north 15° east. Limestone, which was harder than the shales and sandstones, made up these prominent ridges. Lambak shales

[21] Op. cit. [22] Ickis, H. M., op. cit.

and sandstones were eroded from the top of the ridges and were probably preserved in the valleys. These regular ridges and valleys were clearly due to faulting, folding, and subsequent differential erosion making prominent escarpments of the limestone.

On account of the general southerly trend of the ridges, the streams followed the depressions and flowed southward, and undoubtedly cut water graps through the ridges, because the original slope of the region was to the west. The upper course of Angat River is in the basement complex and has not been covered by basalt, so that the present upper bed was also its pre-lava-flow bed. Angat River might have been flowing southward along a north-south depression along the present lower course of Ipo River through the present Mariquina Valley, emptying into a former and greater Manila Bay. Mariquina River may have emptied into the former south-flowing Angat River. When the lava flows came Angat River may have had to seek a new channel.

Just west of this probable old course of Angat River, lies the easternmost line of isolated limestone outcrops. Angat River may have flowed between a limestone ridge and a diorite ridge, so that conditions favoring pseudo-monoclinal shifting may have obtained and a straight water course must have been established.

The relief was probably as great as the present since the lavas which flooded the region filled up the depressions thus decreasing the relief. However, these lavas have been cut into by subsequent erosion.

Folds (*Plate 3*).—All the formations except the Quaternary are more or less folded. Quaternary alluvium has undergone elevation, without signs of folding. The Pre-Miocene sediments evidence the greatest amount of folding. Since their attitudes are about the same, the supposed Jurassic cherts and the Oligocene sediments have probably undergone about the same amount of diastrophism. The Post-Oligocene formations are gently folded and undulated. In several places where the Miocene lavas show pseudostratification, folding is very evident. It was observed that folding in the lavas was more severe than in the later formations. The Alat conglomerates and the Guadalupe tuff are undulating with low, small, broad anticlines and synclines whose axes trend generally in a north-south direction, with variations within 15° east or west.

Between Bakas and Polo there is an anticline (see section along *a–a*, Plate 3) of greater dimension than the other folds,

and followed eastward by a syncline. Their axes follow more or less the general direction of the tectonic lines of the region. Clear stratification in the limestone along Angat River at Suclib (Plate 12, fig. 1) and its vicinity shows very nicely the succession of small folds in the formation, but the general attitude of all the formations is a persistent general dip to the west. At Suclib the limestone strikes north 65° west and dips 12° south. This somewhat abnormal strike is probably due to a displacement by faulting. At Bakas and Polo, the strike also varies somewhat, but it must be remembered that the limestone and shales of the Oligocene have suffered great folding and therefore variations in their attitudes should be expected. At Bakas on the western limb of the anticline, the strike is north 30° west, and the dip is 22° west. On the eastern limb, at Bologan, near Polo, the strike is north 22° east and the dip is 12° east. Suclib is on the eastern limb of the syncline.

At Montalban (see section along *d–d*, Plate 3), there is a very sharp anticline trending about north 24° east. This is well shown in the basal shales and sandstones beneath the limestone. The cross section along line *d–d* (Plate 3) shows the structure at Montalban. The big limestone outcrop there is the eastern limb of a sharp anticlinal fold across which the Mariquina River has cut through exposing the basal sediments of the Oligocene. On account of the absence of lava in the gorge it is evident that the stream had not made the gorge yet when the basalt came, but that this new channel was cut after the other drainage channels had been dammed by the basalt. Wawa Creek follows, more or less, the axis of the Montalban anticline. The strikes vary from north 32° west to north 10° east the west dips from 38° to 82°, and the east dips from 64° east to 79° east. At one place the shales were vertical.

Miocene faulting previous to the lava flows.—The great Post-Oligocene period of diastrophism, besides intensely folding the strata, may have also produced thrust faulting even before the lava flow, especially when we consider that there is a limestone member between shales and sandstones; a hard, brittle, and resistant bed between comparatively much softer and more pliable beds. However, because of the lava flood, evidences are lacking. The folding up of the limestone along Minoyan Creek and at Suclib, together with the propable thrust faulting must have made a barrier which limited the lava flow to the west.

Miocene faulting after the lava flows.—The diastrophism that began after the Oligocene must have continued until after the

lava had solidified, because there are evidences of folding and thrust faulting after the lava flow. At the base of the limestone above Suclib in the vicinity of Pared, no basal Oligocene sediments were found and the limestone is seen resting on top of the younger Miocene basalt. The basalt was clearly not intruded into the limestone, because instead of evidence of contact metamorphism there was observed a great amount of slicken-siding along the contact denoting displacement, and the basalt at the contact is greatly weathered denoting a fault contact. This thrust fault is responsible for the prominent and high limestone outcrops along Angat River and Minoyan Creek.

Besides thrust faulting, these compressive stresses must have resulted in breaks inclined to the direction of the thrust. It is, therefore, probable that cross faults 2 and 3, (see map, Plate 2) may have been initiated at this time.

Post-Miocene faulting.—Doubtless, after the compressive stresses, which resulted in the close folding and thrust faulting, were spent, a settling must have followed producing normal faults. It is possible that with the great overburden of lavas this settling was emphasized and the present normal faults in a general north-south direction resulted.

The earliest movements along fault lines occurred along the east-west cross faults, 2, 3, 5, and 6, because the long north-south faults cut these cross faults. Then followed faults 1, 4, 7, and 8 which were more or less contemporaneous (see map, Plate 2). The cross faults were probably caused by compressive stresses, and the long north-south faults by the reactionary tensional stresses after the compression.

DESCRIPTION OF THE FAULTS

THE CROSS FAULTS

Fault 2.—This fault trends about north 70° west and follows the general direction of the lower Angat River from the mouth of Ipo River. It probably has influenced the general direction of the lower courses of the river. This fault was determined in the field from the alignment of the abrupt turn of Angat River in the vicinity of Ipo River, with the remarkably straight contact line between the limestone outcrop along Angat River and the Miocene lavas. It is an abnormal contact line because the contact lines would be expected to run north-south in keeping with the structure of the region. Besides, faulted blocks have been observed on the southern bank of Angat River at the Ipo dam site. The direction of Angat River

corroborates the evidence. The northern side of the fault appears to be the downthrow side. This fault is probably not active of itself, but any movement along the long north-south principal faults may cause slight adjustments.

Fault 3.—Fault 3 cuts Ipo River at about 2 kilometers from the mouth and trends about south 72° west and follows the general direction of Osboy Creek and Santa Maria River. It meets fault 2 east of Ipo River. It was mapped on two direct evidences. At localities 40 and 44 (see map, Plate 2) Binangonan limestone covered by basalt was encountered at river bottom. At locality 44 this limestone outcrop disappears at a long fault scrap about 2 meters high (Plate 13, fig. 1) where there is a waterfall, and is displaced and continued about 40 meters higher on a ridge. The southern block is the downthrow side; the throw is about 40 meters with a heave of about 60 meters. At locality 46 (see map, Plate 2) a prominent, straight, wide fissure gap in the stream bears about south 78° west, in line with the displaced limestone at locality 44. As corroborative evidence, this fault is in the general direction of Osboy Creek and Santa Maria River.

Movements along fault 3 may only be subsidiary to displacements along the principal north-south faults which cut it.

Cross-faults 5 and 6 are only small local faults and will be discussed later with the system of local faulting in Novaliches River.

THE NORTH-SOUTH PRINCIPAL FAULTS

Fault 1.—This principal fault is a normal fault and has a north-south trend going through Biten-Biten and marks the contact line between the lavas to the east and the limestone to the west in the upper Minoyan Creek. It is marked by a prominent limestone escarpment which is straight and regular until it cuts fault 2. This fault line was extended to the north and to the south on the strength of the abrupt bends in all the streams in line with the escarpment. From the north (see map, Plate 2) the bends occur at Maasin River, Bayabas River, Sapang Balite, Minoyan Creek, the Biniakdan and Katitinga forks of Santa Maria River, Sapang Alat, and Novaliches River. Elongated hills along the fault have also been noticed. It probably joins fault 7 near the southern edge of the present area.

The downthrow side is the western side, although there are escarpments on both sides at Bicti. The western escarpment is a result of the erosion of the shales to the west which are in contact with the limestone. The eastern escarpment is due

to recession by solution of the limestone, which was either overfolded or overthrust on the basalt during the Miocene compressive stresses. The throw of the normal fault is probably small, and so is the heave, and the western block has shifted slightly to the south.

Recently the Metropolitan Water District has started operations on their proposed 7-kilometer tunnel from Bicti to the Ipo dam site. Work was begun at both terminals. The work at Bicti had advanced to more than a kilometer and the contact between the limestone and the andesite was observed closely. A vast amount of slicken-siding was noted in the limestone at and near the contact, showing conclusively that movement must have occurred along this contact.

Thus faults 1, 2, and 3 form a triangular block from which the opposite blocks on the three sides have been depressed by normal faulting.

Fault 7.—Fault 7 is probably a very long fault which marks the western side of Mariquina Valley and trends about north 20° east (Plate 8, fig. 2). North of Mariquina Valley, this fault probably limits more or less the eastern boundary of the basalt area, since it has been reported that Mount Lacotan and Mount Katitinga are made up of diorite. It is in line with a straight trenchlike depression which is very noticeable from the northern edge of Mariquina Valley (Plate 9, fig. 2). This depression passes immediately west of Mount Lacotan and Mount Katitinga and is also more or less in line with the upper courses of Angat River.

At Mariquina Valley (Plate 8, fig. 2) though the escarpment is not well preserved, the material being tuff, it is too straight to have been produced by the mere meandering and sidecutting of the river. It is at this fault trace that Mariquina River makes a right-angle turn to the south, changing its westward course to a southerly one. Moreover, the basalt flow that has its source in the vicinity of Antipolo and constitutes the ridge flanking the eastern side of Mariquina Valley, must have flooded the space occupied by the present valley to connect with the basalt area northwest of the Valley. The disappearance of the basalt in the present Mariquina Valley must be explained by faulting.

Furthermore, this fault can be traced south into Cavite by marked escarpment, even though the material is tuff, and in an alignment of unnatural abrupt bends in the streams in Cavite and Laguna Provinces. It limits the western boundary of La-

guna de Bay. The uplift of the western portion of this fault made the escarpment and is responsible for the separation of Laguna de Bay from Manila Bay. This happened after the Pliocene tuffs were deposited, and is, therefore, comparatively recent.

Fault 7 is the major structural feature in this area. The alignment, in a gentle doubly curved line, of Mariquina Valley, the upper Angat River, the straight abrupt bluff of the Pacific coast between Agria Point and Encanto Point, Casiguran Sound, and the straight Pacific coast between Dinapiqui Point and Disumangit Point may be noted. Southward it may be extended along the fault scarp west of Laguna de Bay, through Taal Lake and the eastern coast of Batangas Bay where it probably stops. This major fault line is shown in the small map of Luzon (fig. 3).

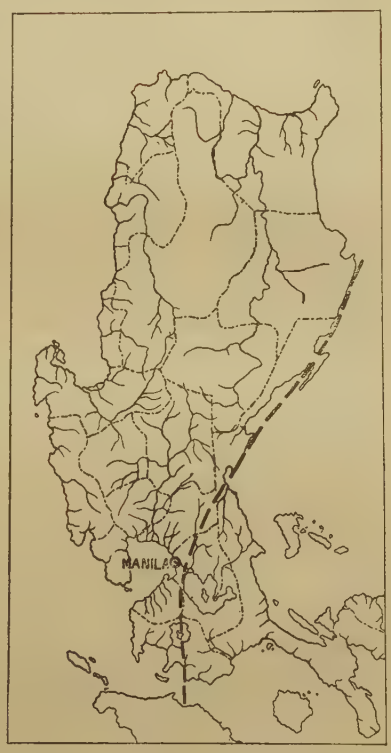

Fig. 3. Northern Luzon, showing the extension of the western fault of Mariquina Valley (fault 7).

In Mariquina Valley the latest movement along fault 7 is probably a tilting to the west of the western block.

Fault 8.—Bailey Willis said that this was the most beautifully preserved fault he had ever seen. It marks the eastern side of the graben occupied by Mariquina Valley (Plate 8, fig. 1; Plate 9). It is very conspicuous because of its prominent and excellently preserved escarpment in basalt. This escarpment rises abruptly from the alluvial plain of Mariquina River and is essentially straight. The escarpment shows faulted valleys and truncated spurs with triangular facets. It probably extends northward to Mount Oro, about 10 kilometers northeast of Montalban town. Toward the south it reaches Laguna de Bay, recurving slightly to the east, and may cross the lake into Laguna and Batangas Provinces. South and southeast of San Mateo, there is a small group of low, rounded hills of basalt

just west of the fault. These low hills represent the downthrow side of the fault. Farther north the downthrow was greater, and no traces of the basalt in the valley are seen. Farther south, the low hills of basalt show that there the throw was less. The throw in this fault must have been considerable if the level of the former lava plateau which must have covered the present site of Mariquina Valley is taken into consideration. Even if 300 meters is taken as the level of the old plateau (there are many places in this basalt range east of Mariquina which exceed this height) and 30 meters as the altitude of the floor of Mariquina Valley, the throw must have been 270 meters or more, because the alluvium is very thick. Opposite and below San Mateo, the throw must have been less. Probably this movement did not take place all at once within recent times, but began during the after effects of the great Post-Oligocene compressive diastrophism and after the lava flows had covered the region. A total throw of 270 meters or even more is not difficult to comprehend when we take into consideration all of Pliocene, Pleistocene, and Recent times. However, the conservation of the escarpment, with faulted valleys and truncated spurs, point to the recency of the greatest part of the movement.

It has been thought that the limestone ridge through which Mariquina River has cut a deep gorge, and in which the dam of the Metropolitan Water District is built, is in fault contact with the basalt on both sides. The writer is of a different opinion, because of its general alignment parallel to the axes of the normal folds of the region, and the general north-south trend of the limestone outcrops everywhere else, it seems that this limestone ridge was a prominent ridge of the Post-Oligocene pre-Miocene topography. It was very closely folded, resulting in the nearly vertical attitude of the strata. Because of its altitude it was not covered but merely flanked by the Miocene lava flows. On account of the hardness of the limestone, the comparative softness of the shales stratigraphically above it, and the close folding, this ridge, similar to the other limestone ridges of the Post-Oligocene pre-lava-flow topography, had a linear and almost straight feature. Therefore, the lava flows had a regular and almost rectilinear contact with it.

Faulting along the upper Novaliches River (see Plate 2 and text fig. 2).—This comparatively small and unimportant system of faulting is interesting because it shows that even small and recent faults in the subsidiary creeks of a river system can be successfully recorded. It is recent since erosion in the soft tuff

has not yet obliterated the topographic expression of this faulting. Under the topic of drainage attention has already been called to this influence of faulting on the upper courses of Novaliches River. The angularity of the pattern above Camates Creek immediately attracts attention. Novaliches River and its branch, Camates Creek, are almost parallel in this vicinity. Then Novaliches River turns an abrupt right angle and meets Camates Creek about 1 kilometer downstream, and turns to the south again. Since the formation here consists of Guadalupe tuff and tuffaceous sediments, which are only slightly inclined, it cannot be that lithologic differences had any influence on the drainage pattern. It will also be observed that the small area between Camates Creek and Novaliches River is lower than either side, and that there are more and longer tributaries to both streams from either side than from the middle area. Fault 5 is reflected east of Novaliches River by a small straight creek, but the line seems to have shifted a little to the north. Fault 6 is reflected in some turns of Novaliches River with a small escarpment as its continuation to the east. Faults 1 and 4 are probably contemporaneous and the cross faults 5 and 6, also contemporaneous and earlier. The more recent faults 1 and 4 have displaced the cross faults horizontally. The relation of the drainage and topography to faulting in this vicinity is clear and interesting. The middle area is a block which was tilted down, with its greatest movement at fault 5 and which probably amounted only to about 10 to 15 meters. In other words the movement was pivotal, with the pivot or fulcrum about 3 kilometers north of fault 5. It is, therefore, true that the system of faulting was already there before this tilting took place, and that this tilting is the most recent movement or at most contemporaneous with faults 1 and 4. This system of faulting was mapped and studied on the strength of criteria derived from the drainage pattern and the peculiar topography, and not from lithologic, structural, or other criteria. All these faults are normal faults.

Joints.—Joints are conspicuous and had doubtless influenced many of the erosional features. A few observations were taken, and free use was made of the notes on jointing by H. G. Schenck, who did some work along Angat River and in Sapang Laan, north of Montalban town.

Above the mouth of Ipo River, on Angat River, there are two predominating sets of joints, one trends northeast and the other east-west. There is an obscure suggestion of a north-

west joint which may have been due to a thrust from the west, and which may be the latest. Hartmann's law says that for brittle substances the acute angle of fractures is bisected by the greatest tension or easiest relief. Therefore, above Ipo River, where the joints trend east-west and northeast, the thrust must have come from the southwest with a bearing of about north 68° east or from the northwest, south 68° west.

In the vicinity of Paila the joints have the following dips and strikes:

1. Strike north 30° east, dip southeast, predominant.
2. Strike north 20° west, dip southwest, doubtful.
3. Strike north 25° west, dip 50° southwest, probably the same as 2.
4. Strike north-south, dip 70° west, dikes and some joints.

Set 4, which is inconspicuous, is probably due to the rotational strain produced in the flank of an anticline as a result of a thrust from west to east.

The rest are hard to explain from Hartmann's law, because then the thrust would have had to come from the north or from the south; but the folding and the structure point to a thrust from the east or west, and these joints may not be due to compression. It is very probable that these joints are tension joints because after the Middle Miocene tensional stresses have been the rule as previously explained. It is, of course, to be expected that, when the lava cooled down, contractional joints resulted, and open joints have been observed. Therefore, it is surmised that the joints due to compression are the oldest, because of the great compression of Post-Oligocene age, and the tension joints are the youngest due to the settling after the compression and the cooling of the lavas. It is also significant that the compression joints are mostly found above Ipo River beyond the area of lava flows, in basement complex rocks, and the tension joints generally in the lava area.

At Sapang Laan, according to Schenck,[23] north of Montalban, there are two sets of joints, with directions of north-south and north 30° east, similar to those at Paila. These joints are in basalt and are also probably tension joints.

It must not be forgotten that the Pliocene and later sediments are also folded, though the folding is slight. This folding must have been due to compressive stresses which probably took place some time during the Quaternary. Whether any of the sets of joints are due to this last compression or not, has not

[23] Philip. Journ. Sci. 20 (1922) 57.

been determined. At Sapang Laan, the north-south set of joints may be due to tension, or to rotational strain.

Doubtless the angular broken course of Angat River and many of its tributaries is controlled mainly by the different sets of joints. Faulting may have also helped, especially in the general direction of the rivers, but it must be remembered that faults may be defined as joints where appreciable relative displacement has taken place.

Intense, complicated, and irregular jointing or shattering has taken place in the Binangonan limestone as a result of the compressive stresses when it was folded after the close of the Oligocene. The different sets of joints are hard to understand, and this detail in structure has not been deciphered.

Dynamic metamorphism.—The Binangonan limestone is probably of an organic origin, because corals and other fossils have been observed, especially from locality 42 to locality 45 where there is a long ridge of limestone, corals and other fossils were very abundant. Because of the great compressive stresses at the close of the Oligocene, and extending into the Miocene, most of the fossils have been obliterated or at least obscured, and the limestone has become very crystalline, in some places so coarsely crystalline that the term marble might be used. In many places flat flakes of limestone about 1 inch thick and 3 to 5 inches in diameter with very good slickensided surfaces are common. These are due to the gliding between the shattered pieces during the adjustment which resulted from the great compressive stresses above mentioned.

The thin and sometimes concentric laminations of the Lambak shales, and their hardness, are also greatly due to dynamic metamorphism.

The hardness of the Jurassic (?) cherts is doubtless a result of cementation, old age, and dynamic metamorphism. Its lamination is due to its original deposition because the different laminæ are either persistently green or red. Compressive stresses have folded and jointed these cherts.

Seismologic considerations.—June 3, 1863, a disastrous earthquake occurred in Manila and its vicinity. The axis of the mezoseismic area, according to Father M. Saderra Masó,[24] followed the direction of the Eastern Cordillera.

From the map on page 280 (of Smith, op. cit.) the present area is included in the seismic region. None of the seismotectonic lines coincide even in a general manner with the faults that have

[24] Bu. Sci. Publ. 19 (1925) 285.

been studied in the area. If the axis of the mezoseismic area followed the direction of the Eastern Cordillera, which trends almost north-south, the movement could not have been along the above-mentioned lines. And since the mezoseismic area was west of the Eastern Cordillera, it could not have been due to the seismotectonic lines east of the Eastern Cordillera.

From a study of the structure of the area under consideration it seems most probable that the movement must have taken place along both faults of Mariquina Valley, faults 7 and 8. It is possible that movement also occurred along fault 1, but it was probably only subsidiary to the other faults. Of the two faults of Mariquina Valley, it has not been ascertained which is the more active because the western fault, 7, is not as clear cut as the other, but it has a much longer extension; while the eastern fault, 8, although comparatively short, has a greater inequality in balance on both sides, and its escarpment is comparatively fresh. However, fault 7 is a major structural fault, and is probably the more active.

If displacements occur in faults 7 and 8, and in consequence, also along fault 1, minor adjustments will result in the cross faults. It is possible that on account of these minor adjustments these cross faults are beneficial in that they may take up some of the movement and may minimize the shock.

Since Mariquina Valley is a graben where sediments are gradually accumulating and the regions on both sides are constantly being denuded; and since these faults here are very recent, it is only to be expected that movements should occur along them at present. Being normal faults, with probably little or no horizontal heave, the shocks imparted will have two components, one vertical and the other horizontal at right angles to the fault traces, or in a direction between north 60° west and north 70° west.

Minor adjustments along fault 1 may result in a horizontal oscillation with a general north-south direction, because it is believed that in fault 1, a horizontal north-south displacement along the fault trace has occurred. However, these shocks should not be as marked as the others.

GEOLOGIC HISTORY

Since the oldest sediments are the probable Jurassic (?) cherts and the next oldest are the Oligocene sediments, the geologic history of this region which can be read from the records accessible to mankind will be comparatively short and recent.

However, an attempt will be made to decipher the history contemporaneous with the intrusions of the granite and the old basement complex rocks. All that is certainly known regarding these rocks is that they are older than the Jurassic, and that the granite is the oldest rock.

PRE-TERTIARY HISTORY

Paleozoic times.—During Pre-Permian times, the Philippine Islands were at the very edge of the broad continental shelf of Asia. The South China Sea basin had not yet been depressed. On account of its great distance from the mainland of Asia, Paleozoic sediments may not have reached the edge of the continental shelf, except, in all probability, a small amount of extremely fine clastics. It was too far from land, and probably too deep for littoral faunas. This explains the absence of recognizable Paleozoic sediments and fossils.

The intrusion of granite.—Sometime during the early Paleozoic, there were small local stock intrusions of granite and other allied rocks, and a small amount of grano-diorite. Some of the magma may have reached the surface, or near the surface, because samples of rhyolite have been collected. In all probability these rhyolites were, therefore, extruded under water. One of the localities intruded by these acid rocks is the granite area in Bulacan Province. There was a slight up-bowing or doming of the crust which probably slightly affected parts of the Angat River area, especially north of the river. The Philippine Islands were still under water and did not yet have the present configuration.

The Permian revolution.—Paleontologic evidence points to the existence of the South China Sea during Triassic times. If this is true, then the basement complex basic rocks, which form the backbone and the framework of the structure of the Philippine Islands, must have been intruded before the Triassic because the Philippine Islands is the barrier that cuts off the South China Sea from the Pacific. As the closest and most probable period of diastrophism before the Triassic is the great world-wide diastrophism during the close of the Permian, it is extremely probable, that it was during this time that the depression of the South China Sea basin occurred with a contemporaneous intrusion of basic rocks in the area now occupied by the Philippine Islands. If the thrust resulted from the depression of the basin of the South China Sea, then we should expect the crust to have been folded along a north-south axis,

and the intrusion to be elongated in the same direction. Since we have no Paleozoic sediments, the Permian or Pre-Triassic folds could not be observed, but the areas of coarse basic rocks are elongated north-south. Therefore, it is very probable that during the Permian diastrophism, the South China Sea was depressed, the basement complex rocks of the Philippine Islands were intruded, with their associated hypabyssal and extrusive equivalents, and the present configuration of the Philippine Islands was outlined, as far as the skeleton and frame work is concerned. However, even if the Philippine Islands formed a barrier for the South China Sea, they had not yet been elevated above the water. This is in keeping with the belief that the principal mountain ranges of the East Indies, Java, Sumatra, Borneo, etc., were formed also at this time.

MESOZOIC

Deposition of the Baruyen cherts.—At the beginning of Mesozoic times, therefore, the South China Sea was already a basin isolated from the Pacific Ocean by the elongated batholithic intrusions of the basal complex rocks of the Philippine Islands. The area of the Philippines was probably still too deep for corals or other shallow-water fauna to flourish. No coarse sediments of the Mesozoic have been discovered. The probable Jurassic cherts are the only recognized Pre-Tertiary sediments, and they have very poor and very limited outcrops. Consequently detailed sections are quite impossible. Smith[25] has called the cherts the Baruyen cherts in Ilocos Norte, to which a probable Jurassic age has been assigned. There are two phases of this chert as heretofore explained under Stratigraphy. One is red chert or jasper, which contains fine angular grains of feldspar and some quartz embedded in the red hematitic and opacitic semicrystalline silica. In these red cherts radiolarian tests have been found by Smith and by the writer.[26] The other phase is a green chert which owes its color either to chlorite or to glauconite. It is very fine microcrystalline chalcedonic or opaline silica, and feldspar grains are very rare. No radiolarian tests were observed in this green chert. These two phases of the chert alternate irregularly in the beds. It is probable that the red cherts were deposited in times of great devastating floods in the mainland of Asia, carrying in their turbulent waters the fine sediments. It is significant that these cherts have not been

[25] Op. cit. 72. [26] Loc. cit.

found in the eastern part of the Philippine Islands. It is also probable that during those times there was a greater mortality among the radiolarians. The green chert may be ascribed to deposition during quiet and peaceful times.

These probable Jurassic cherts are the only Mesozoic sediment found. Doubtless there should have been sea deposits during the Triassic. There is the great probability that these cherts represent not only the Jurassic, but also the Triassic, and the Camanchean—probably all of Mesozoic times before the intrusion of the ultra-basic rocks which probably occurred during the Cretaceous. This statement is merely suggested to fill the gap in the geological history of this region, because there are no records except the Baruyen cherts. Under this hypothesis, the Philippines had not yet emerged above the sea.

Intrusion of the peridotites and pyroxenites.—In Zambales, Elicaño [27] found hornblendite intrusive into the cherts. Smith[28] says that in Ilocos Norte and other parts of the Archipelago pyroxenites and serpentinized rocks probably belong to the part in the column that is intrusive into the Mesozoic sediments. It is very probable that during the Mesozoic, after the deposition of the cherts, the third great intrusion occurred, and its predominating rocks were pyroxenites and peridotites. It is true that this intrusion could have occurred at the end of the Mesozoic or even during Eocene times. A study of the composition of the Agno conglomerates, in Baguio and its vicinity, which are supposedly Eocene, might solve this problem. However, among the geologists who attended the Third Pan-Pacific Science Congress at Tokyo in 1926, there is a concensus of opinion that the ultra-basic intrusion which happens to be general from Japan, through the Philippines and the East Indies to New Zealand, occurred during the Cretaceous.

The close of the Mesozoic.—Great, world-wide, epeirogenic movements brought the Mesozoic to a close. These great continental uplifts changed sea bottoms to dry land. They inaugurated Tertiary geologic history, and for the first time the Philippine Islands emerged from the water. It was the dawn of erosion.

TERTIARY

The absence of Eocene sediments.—In the area under discussion no Eocene sediments have been observed, but in Baguio and its vicinity the Agno conglomerates, of probable Eocene

[27] From field notes of V. Elicaño, Bureau of Science, Manila.
[28] Bu. Sci. Publ. 19 (1925) 76.

age, are present. These conglomerates indicate the existence then of islands of moderately high relief. The absence of Eocene sediments in the Angat-Novaliches region may be due to one of several causes. The area may have been land and the Eocene sediments never deposited; or, if they were deposited, they may have been eroded off or covered by the later sediments. It is probable that the area of the Eastern Cordillera was suffering erosion while deposition was being made on its flanks. The land continued to be uplifted, and whatever Eocene sediments may have been deposited, subsequent erosion after exposure may have obliterated them. More-extensive Eocene sediments, therefore, might be encountered under the epicontinental sea of the Philippine Islands, because there was a greater land area near the close of the Eocene that at present or any other time. The basis for this opinion is as follows. Oligocene coal strata in Mindoro and Batan can be correlated between islands. The coal seams in Bulalacao, southeastern Mindoro, cross over to Semirara Island, and the coal seams in Albay cross to Batan Island, and are exposed at the sea shores. To have a coal deposit, lagoons or swamps wholly or nearly surrounded by land is necessary since coal cannot be deposited in the open sea. Therefore, the land must have been more extensive then than to-day. These coal strata are of lower Oligocene age and above these we have the Oligocene limestone. A gradual subsidence of the Islands was in progress at the beginning of the Oligocene.

THE OLIGOCENE

After a long period of erosion during the continued uplifting of the Eocene times, the upward movement was reversed, bringing the Eocene to a close and inaugurating the Oligocene. From that time, the history of this area is based on substantial evidences, since there are representative deposits of the Oligocene and all ensuing epochs.

First, of course, the basal Oligocene conglomerate was deposited. This was very thin and may indicate a rapid subsidence of the land. Then the thin layer of lignite, found near Matictic, was laid down at a time when the land was oscillating near sea level, and the downward movement was either temporarily arrested or became slower and more gradual. Associated with the coal, the dark, unfossiliferous shales of the Lower Oligocene were deposited. Most of the coal seams in the Philippine Islands were laid down at this time. Then the region continued to sink. The water must have been clear and warm when the Binangonan limestone was deposited, as

it contains coral, *Lepidocyclina, Lithothamnium ramosissimum,* and other fossils. Toward the close of the deposition of the limestone, and during the earlier deposition of the Lambak shales, the Philippine Islands experienced the greatest submergence since they were uplifted from the sea. Toward the latter part of the Oligocene, conditions must have changed, and the Lambak shales and sandstones were deposited. An upward movement had then been initiated resulting in a shallower sea, and coarser clastics were deposited. The comparatively hard greenish Lambak shales were probably deposited when the sea bottom was still relatively deep, because they are very fine sediments, and the green color is due to either chlorite or glauconite. The coarser clastics, as the sandstones and the tuffaceous sandstones, were the last of the Oligocene sediments to be deposited. The tuffaceous sandstones imply minor volcanic activity during the latter part of the Oligocene.

THE MIOCENE

Post-Oligocene or Miocene diastrophism.—The Oligocene was brought to a close by the greatest diastrophism in Tertiary times ever experienced by the Philippine Islands, and which lasted till the end of the Miocene. The attitude of the oldest sediments, the Baruyen cherts, is very similar to that of the Oligocene sediments. Consequently it is improbable that the cherts had been disturbed by any appreciable orogenic movements before this time. Great compressive stresses from the west folded the Oligocene and older sediments into very sharp anticlines and synclines trending about north-south to north 30° east. Locally, these folds lifted the land out of the water. Thrust faulting may have resulted from this thrust from the west making prominent bluffs of limestone. The direction of faults 2 and 3 point to a possibility that they were inaugurated during the compressive stresses, and that they may be ruptures inclined to the direction of compression. A moderately long period of erosion set in during the lower Miocene which etched the topography. The limestone, being harder than the rest of the Oligocene sediments, stood out as more or less straight and regular ridges, the crests of the sharply folded anticlines. The general slope of the region was to the west, but the streams flowed in a general southerly direction, due to the limestone ridges. Doubtless, water gaps were cut across these ridges. Angat River probably flowed southward into the former and larger Manila Bay, and Mariquina River may have emptied into this older Angat River.

Lava flows.—The Miocene dawned on a land area which was being subjected to great compressive stresses and at the same time was suffering fast tropical weathering and erosion. It must be remembered that this diastrophism continued until after the Middle-Miocene lavas had been extruded, but it is believed that it was strongest at the outset.

Miocene sediments, whether terrestrial or marine, have not been found in this area. Volcanism, in the form of lava flows, played the principal rôle during this phase of the history, in the Middle Miocene. It flooded a land area of mature topography carved during the Lower Miocene.

The first lava flow was a basalt which gathered and included in it the alluvial material made and deposited by the Lower Miocene rivers (fig. 22). The term volglomerate has been proposed for this type of flow. Former geologists have all noted this formation and they have termed it, "volcanic agglomerate," "andesitic agglomerate," and "basaltic agglomerate," but it is not truly an agglomerate because of the heterogeneity of the included material, which is very different from the including or surrounding basalt matrix. Besides, the included material is generally rounded, and not angular. This first flow must have flowed in fingerlike tongues up the valleys, between the ridges.

The next lava flow is the Antipolo basalt proper, which may have been just a later phase of the first flow. This flow probably originated from the region just north of Antipolo, because the altitudes of the basalt there reach 400 meters, or more. The basalt range just east of Mariquina Valley also approximates this height, being close to its probable source. At or near Angat River, the basalt rarely exceeds 300 meters in height. This second flow almost covered the whole region under discussion. Only the higher basement complex ridges and some of the higher portions of the limestone ridges were not covered. This flow was limited in its spread by the limestone ridges and bluffs near Paila and along Minoyan Creek. At the eastern portion it was limited by the diorite ridge along the major fault 7. Toward the west it deployed, and due to the absence of obstacles, it must have spread far and wide with consequent thinning and low elevations.

The third and last flow was the porthyritic Mariveles andesite. This andesite is now found only along a comparatively narrow belt on the western part of the lava area, and is not very thick. No evidence has been found pointing to its source, but

the highest altitude at which it is found is less than 200 meters and its source must have been lower than the source of the basalt, and probably from a different vent. Andesite has been reported east of Mariquina Valley, but the relationships are not known by the writer.

These flows, of course, dammed the rivers of that time and the water had to seek new channels. The weight of the basalt must have caused added displacements in the normal faulting which occurred after the compressive stresses were spent. The cooling of the lava also caused contractional or tensional stresses which resulted in joints and which later helped the movements in the normal faults. The rivers, in their search for a waterway, took advantage of these faults and joints. This explains why the faults have influenced so much the general directions of the rivers; their minor zigzagging or broken-line courses were controlled mainly by the jointing.

Mariquina River may not have been flowing through its present limestone gorge, but due to the lava damming its old course, it cut a gorge through the limestone ridge, which was not as hard, and was full of fissures and solution cavities.

The graben of Mariquina Valley was formed when tensional stresses prevailed, although its latest movements must have occurred within Recent or Pleistocene times.

The Miocene may be summarized as an age of great volcanic extrusions.

Miocene intrusions.—In the Angat iron-ore district, north of Angat River, the instrusions which brought up the magnetite and hematite deposits occurred during the Miocene, because Binangonan limestone was intruded and metamorphosed by it. A section of this limestone was observed under the microscope. It contains the *Lepidocylina* found in the Binangonan limestone and is clearly intruded by the basic magnetitic magma. These intrusions are probably contemporaneous with the Miocene lavas, which are characterized also by a great amount of magnetite disseminations. They may be the intrusive and extrusive equivalents of the same magma.

THE PLIOCENE

After a comparatively short period of erosion of the Miocene lava plateau, the Pliocene was inaugurated by a gradual subsidence of the land and a consequent spreading of the seas. This submergence was not as extensive as the Oligocene, and in the area under discussion its farthest encroachment is more or

less outlined by the eastern contact of the Pliocene Alat conglomerates. The Alat conglomerates were deposited on a sinking littoral area, and do not exceed 35 meters in thickness. These basal conglomerates gradually grade into the finer clastics, tuffaceous sediments, and andesitic tuffs of the Guadalupe tuff formation, which was laid in a shallow-water area. This tuff forms a blanket which more or less covers the whole of the Central Plain, but for the Quaternary alluvium. Its thickness varies and may reach more than 300 meters, but in the area under consideration it probably does not exceed 130 meters.

This great amount of tuff marks the Pliocene as a period of great volcanic explosions. No Pliocene lava has been encountered. Several volcanoes around as well as those in the Central Plain must have contributed to this extensive tuff deposit. Most of the ejecta that fell on land was carried to the sea by running water.

The tuff must have almost filled the shallow-water basin in the Central Plain before a gradual emergence or uplift began that has continued, in spite of oscillations of greater or less degree, to the present time. This marked the close of the Pliocene. Slight folding occurred with emergence causing the gentle undulation of the Pliocene deposits.

THE QUATERNARY

The quaternary is largely a history of emergence and erosion, a continuation of the interrupted erosion of the late Tertiary, and its consequent gradual rejuvenation.

On account of the gradual emergence since the close of the Pliocene to the present time, it is not possible to differentiate between Pleistocene gravels and Recent gravels. The highest altitude at which the Alat conglomerates are now found is about 165 meters. This probably was the relative level of the Pliocene sea at its greatest extent; thus, we may take 165 meters as the elevation since then to the present.

Around Novaliches the highest altitude of 135 meters is made up of well-stratified tuff, with little or no alluvial material at the summits of the flat hills with accordant levels. This portion may have been uplifted from under the water and not formed by alluviation. It is only to be expected that the portion toward the south would have been the last to emerge.

During the Pleistocene or Recent movements again occurred along the fault lines, and fault 7 became active. The Guadalupe tuff on its left side was uplifted and tilted upward, ac-

complishing the separation of Laguna de Bay from Manila Bay. This movement probably amounted to 35 meters or more. Movements along all the other faults occurred also, cutting into Pliocene sediments. Along fault 8 the escarpment is so well preserved that recent movements cannot be denied.

Erosion continued, and the Miocene lava plateau is already well dissected, but its remnants are still so conspicuous that geologists who have visited the region have often suspected peneplanation.

ECONOMIC CONSIDERATIONS

The Montalban reservoir.—At present the water supply of the City of Manila comes from the Montalban reservoir (Plate 1; Plate 19, fig. 1). A dam was built across the Mariquina River at the gorge where the river cuts through limestone. The water is piped to the concrete reservoir at San Juan, where the water is treated with calcium hypochlorite and distributed to the public. During the dry season the reservoir at Montalban almost always goes dry and Manila suffers a shortage of water. To remedy the shortage of this important commodity, the Metropolitan Water District has started operations on the Angat project.

The Angat water project (*Plate 4*).—It is proposed to dam Angat River, just below the mouth of Ipo River (Plate 15), to give Manila an adequate water supply. Angat River has a much greater watershed than Mariquina River and during the dry season, when its flow is smallest, there is more water than would be needed to supply Manila for many years to come. Of the 1,300 gallons per second at its smallest flow (the drought of 1912), only about 300 gallons per second will be needed to insure Manila against any water shortage. From the proposed Ipo dam, the water will be conveyed through tunnels and pipes to the Novaliches reservoir.

The Novaliches reservoir (*Plate 16*).—This reservoir is the watershed of Novaliches River above La Mesa. It is a natural reservoir made by river erosion in the uplifted Pliocene terraine of Guadalupe tuff. By the construction of an earth dam across Novaliches River at La Mesa, a large artificial lake will be created. This dam, which consists of an earth embankment, has already been constructed.

After this reservoir is put in operation, it will temporarily aid the Montalban reservoir with the water collected in the Novaliches watershed above the dam and will materially help

in tiding over the dry season. When the Ipo dam and the water line from there to Novaliches reservoir are constructed, the Montalban reservoir will be abandoned. From the Novaliches reservoir, the water will be piped through the Payong aqueduct to sand filters where the existing pipe line from Montalban is met. From there, the old pipe line will be utilized to convey the water to the San Juan reservoir where it is treated with calcium hypochlorite before distribution.

There was some difficulty in the construction of the dam at La Mesa, Novaliches, on account of the great porosity of the Guadalupe formation. Even the fine tuffaceous shales are very porous, and sandstone layers abound. It is feared that seepage will be great.

The water of Angat River has been analyzed chemically and bacteriologically, and found to be excellent, even for drinking purposes.

Other geologists and engineers have been at work along Angat River in conjunction with this water project. Two dam sites were proposed, one at Pared or Paila (Plate 6, fig. 2) and the other one at the Ipo dam site. The Pared dam site is much narrower, but the water is much deeper. At the Ipo dam site the river is wider, but it is very shallow. Both dams are in basalt. The Ipo dam site has definitely been decided upon. Plate 3 shows the aqueduct from the Ipo dam site to the Novaliches reservoir and from there to the filters.

Power.—The enormous quantity of water flowing through Angat River at once suggests the idea of harnessing this water power. This was the the idea of the late Assistant Manager of the Metropolitan Water District, Federico Muñoz.[29] He proposed to build a power plant in conjunction with the dam for the water-supply project.

Artesian wells.—Due to an absence of impervious capping many artesian wells in the lowlands in the western part of this region are pumping wells. The wells are in Guadalupe tuff, which is so porous that there is always sufficient water in the rocks. An appreciable dip in this formation, however, helped by some sort of local capping has given rise to some flowing wells. But it is hard to explain why most of the wells in the

[29] Preliminary Report on the Angat River Water Supply and Hydroelectric Power Development, Metropolitan Water District publication, Manila (1921).

plains of Bulacan are flowing wells, since many of them are either in alluvium or in delta sediments.

Adobe stone.—At Santa Maria, Balintawac, Novaliches, and other places, the volcanic tuff of the Pliocene Guadalupe formation is quarried for building stone. It makes a very popular and cheap material for construction. It is quarried near the surface, and the excavations seldom reach a depth of 2 or 3 meters, on account of the ground water which fills them.

Road metal, sand, and gravel.—Basalt and andesite for road construction could probably be quarried profitably in several places. From favorable localities near Montalban and on Angat River basaltic material could be transported on rafts. Sand and gravel are abundant along the lower course of Angat River and Mariquina River. However, because of the presence of much basaltic material, this sand and gravel are not ideal for concrete work on account of the great amount of ferromagnesian minerals.

LIMESTONE

Lime.—The name of the barrio Apogan means limekiln. The people from there say that many years ago, limestone, which was obtained from the outcrop along Minoyan Creek, only about half a kilometer away, was burned for making lime.

Near the reservoir at Montalban on the northern side of the river limestone was burned in two or three places. The burning used to be done in small primitive open kilns and the production was very limited. Recently, however, a modern plant has been installed by the Philippine Lime Corporation. This plant has the advantage of the road to the reservoir; and production is going on at full blast.

Building purposes.—The limestone in Montalban Gorge has been utilized in making the gate house and the Montalban dam. It makes a strong and beautiful construction material. However, the limestone here is so badly broken up that production on a large scale would be problematical. At Bakas, above Matictic, the limestone is very massive and very white, but the outcrop is so small that it would not pay to quarry it.

Guano.—There are many caves in the limestone, especially along Minoyan Creek, Angat River, and at Montalban Gorge. Small quantities of guano are obtained in these caves from time to time.

Coal.—A small thin seam of lignite has been discovered in the black shales near Matictic, but it is of little or no economic importance. The discovery of good seams of fair coal would

be welcome in this region to aid in the development of the iron deposits of Bulacan, since coal is essential in the iron industry. Some lignite seams have also been reported in the vicinity of Montalban Gorge,[29] and along Puray River.

Gold.—Gold has been reported from the alluvium of Angat River and Mariquina River but in such small quantities that its exploitation would not pay. At Mariquina River an attempt was made at dredging, but it was not successful. At San Jose del Monte, Bulacan, gold is being recovered from the river gravels by means of cradles. The designs for these cradles were supplied by the division of geology and mines, Bureau of Science.

RÉSUMÉ

1. Granite is the oldest known rock in the Philippines and is probably Paleozoic.

2. The basement complex rocks were intruded during the close of the Paleozoic giving the Philippine Islands their general delineaments under the sea, and this was contemporaneous with the depression of the basin of the South China Sea.

3. The third intrusion consisting of pyroxenites and serpentines occurred after the Jurassic and before the Eocene, that is, during the Cretaceous.

4. The Eocene was a period of wide-spread emergence when the Philippine Islands had the greatest land area in their history. This was the first time that the Philippine Islands were above the water.

5. The Oligocene was a period of submergence, which was the greatest since the Islands emerged. There was also slight volcanic activity.

6. The Binangonan limestone and the sediments conformably below and above it are of Oligocene age.

7. The greatest deformation suffered by the Philippines occurred at the close of the Oligocene and extended through the Miocene.

8. The compressive stresses of the Post Oligocene-Miocene deformation was due to a thrust from the west, producing in the Angat-Novaliches region, thrust faulting, and intense folding with axes trending in a general north-south direction; they also initiated the cross faults 2 and 3. These compressive

[29] Becker, B. F., Report on the Geology of the Philippine Islands, 21st Ann. Rept. U. S. Geol. Surv. (1899–1900) 84.

stresses persisted to the end of the Miocene but were probably strongest at the outset.

9. The principal north-south faults were initiated during the settling after the compressive stresses were spent, probably during the Pliocene or Quaternary. The overburden of lava has added greatly to these settling adjustments which may persist to the present day.

10. Erosion to maturity occurred before the extrusion of the lavas when the Angat River may have flowed southward to the older and larger Manila Bay.

11. The Miocene was the age of volcanic extrusions resulting in a lava plateau. Intrusions also occurred just north of this area giving rise to the iron deposits of Bulacan.

12. The Pliocene was a period of submergence and of great volcanic explosions, which resulted in thick, stratified, tuff deposits.

13. There is a thin littoral conglomerate, with cross-bedding and local unconformities at the base of the Pliocene.

14. The Pleistocene was initiated by an upward movement which has continued with oscillations to the present time, amounting to an uplift of about 500 feet.

15. Fault 7 is a major structural feature and can be traced topographically from Batangas Bay to the northeastern Pacific coast of Luzon, and is responsible for the separation of Laguna de Bay from Manila Bay.

16. Mariquina Valley is a graben.

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[33] Derived from G. F. Becker, op. cit; W. D. Smith, Geology and Mineral Resources of the Philippine Islands (1925); H. G. Ferguson, manuscript; and some additions by the author.

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ILLUSTRATIONS

PLATE 1

The Metropolitan Water District dam at Montalban Gorge.

PLATE 2

Areal geologic map of the Angat–Novaliches region.

PLATE 3

Geologic cross sections of the Angat–Novaliches region.

PLATE 4

The waterworks project of the Metropolitan Water District in the Angat-Novaliches region.

PLATE 5

View northeast of the railroad depot at Montalban.

PLATE 6

FIG. 1. Novaliches reservoir, showing the rolling topography.
2. Pared, Angat River, looking upstream.

PLATE 7

FIG. 1. The cañon of Mango River, a detail of the fault scarp on the eastern side of Mariquina Valley, showing the triangular facets of the spurs.
2. A view of the cañon of Mango River.

PLATE 8

FIG. 1. The basaltic range east of Mariquina Valley, showing the fault scarp of fault 8.
2. The scarp of fault 7 on the western side of Mariquina Valley, showing the uniform altitude of the tuff hills.

PLATE 9

FIG. 1. Angat River about 1 kilometer from Ipo. Note the even skyline.
2. The long straight trench along fault 7, occupied by Pagup River, west of Mount Lacotan.

PLATE 10

Binangonan limestone outcrop at Bicti, showing the broken character of the rock and the rain solution channels.

PLATE 11

FIG. 1. Dacitic dike rock in basement complex rocks at Pared.
2. Basaltic volglomerate in Ipo River. The included pebbles are mostly diorite with some gabbro.

PLATE 12

FIG. 1. Well-stratified Binangonan limestone dipping downstream at Suclib cave.

2. The mouth of the underground river from locality 22 to locality 26 on Angat River, showing Binangonan limestone, caves, and terminals of underground passages.

PLATE 13

FIG. 1. Locality 44. Waterfalls on fault scarp across Osboy Creek (fault 3). The stream bed in the foreground is limestone. The escarpment is basalt.

2. Lower Oligocene sediments, shales, and conglomerate near Polo, locality 27 on Angat River.

PLATE 14

FIG. 1. Quartzitic dikes in basement complex rocks at Pared.

2. Alat conglomerate below quaternary alluvium at Sapang Alat, locality 55.

PLATE 15

The Ipo dam site, on Angat River, looking upstream.

PLATE 16

FIG. 1. The Novaliches dam of the Metropolitan Water District under construction.

2. Novaliches dam of the Metropolitan Water District nearing completion.

PLATE 17

Interior of a cave at Montalban.

PLATE 18

FIG. 1. Basal Oligocene shales and sandstones at Montalban Gorge showing the steeply dipping beds.

2. Interior of a cave at Montalban.

PLATE 19

FIG. 1. Montalban Gorge, when dry.

2. Mariquina River just below the Metropolitan Water District dam, showing large limestone bowlders in the stream bed.

PLATE 20

FIG. 1. Anorthosite, near Pared, on Angat River. Note the large amount of magnetite.

2. Radiolarian test in the red cherts of locality 3, Ipo River.

PLATE 21

FIG. 1. Fine clastic grains, mostly plagioclase, in the red cherts of Ipo River.

2. Post Jurassic augitite, porphyritic with a glassy to hypocrystalline groundmass.

PLATE 22

FIG. 1. Porphyritic basalt from the mouth of Ipo River, showing labradorite phenocrysts and a groundmass of dark-green chloritic glass. Miocene.
2. Variolite from the tunnel of the southern bank of Angat River at the Ipo dam site. Miocene.

PLATE 23

FIG. 1. Variolite, showing spherulites and axiolites of chlorite. Miocene.
2. Tachylite, with matrix of volglomerate and a black portion of intruded dark-green chloritic glass. Miocene.

PLATE 24

FIG. 1. Andesite at mouth of Biniakdan Creek, locality 60, showing andesine, hornblende, and magnetite in a cryptocrystalline groundmas. Miocene.
2. Calcareous andesite or andesitic limestone, taken from limestone near the andesite contact at locality 53, Katitinga Creek.

PLATE 25

FIG. 1. Binangonan limestone near the andesite contact at locality 53, on Katitinga Creek, showing fossils and fragments of plagioclase and hornblende.
2. Binangonan limestone.

PLATE 26

FIG. 1. Foraminifera in Binangonan limestone from locality 53, Katitinga Creek.
2. Characteristic lepidocyclina in Binangonan limestone from locality 53, on Katitinga Creek. This fossil is found in all the limestone outcrops although it is hard to distinguish.

PLATE 27

Lepidocyclina in Binangonan limestone from locality 53 on Katitinga Creek.

PLATE 28

Montalban Gap.

TEXT FIGURES

FIG. 1. Index map.
2. Faulting at Novaliches River.
3. Map showing the extension of the western fault of Mariquina Valley (fault 7).

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PLATE 1. THE METROPOLITAN WATER DISTRICT DAM AT MONTALBAN GORGE.

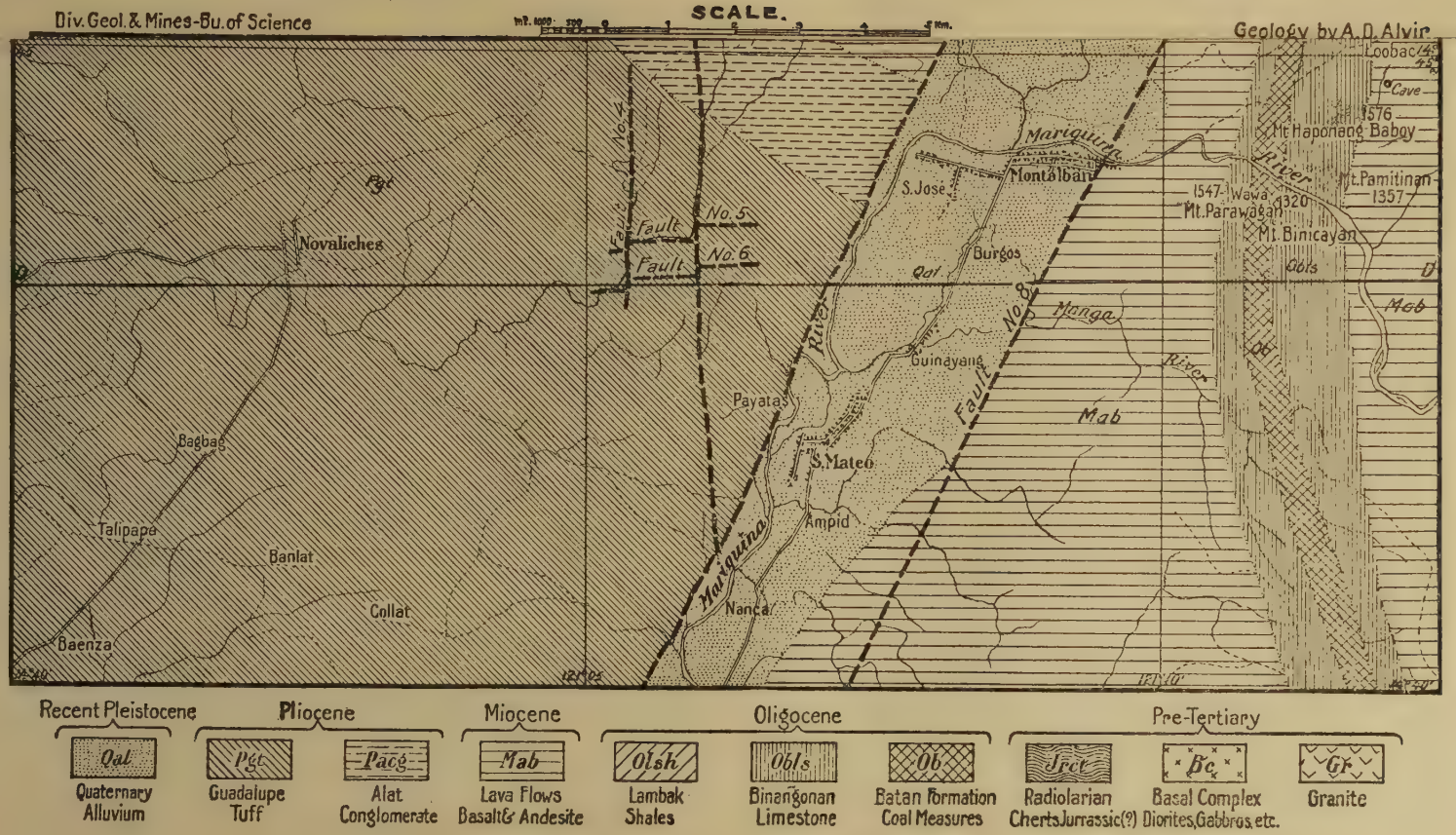
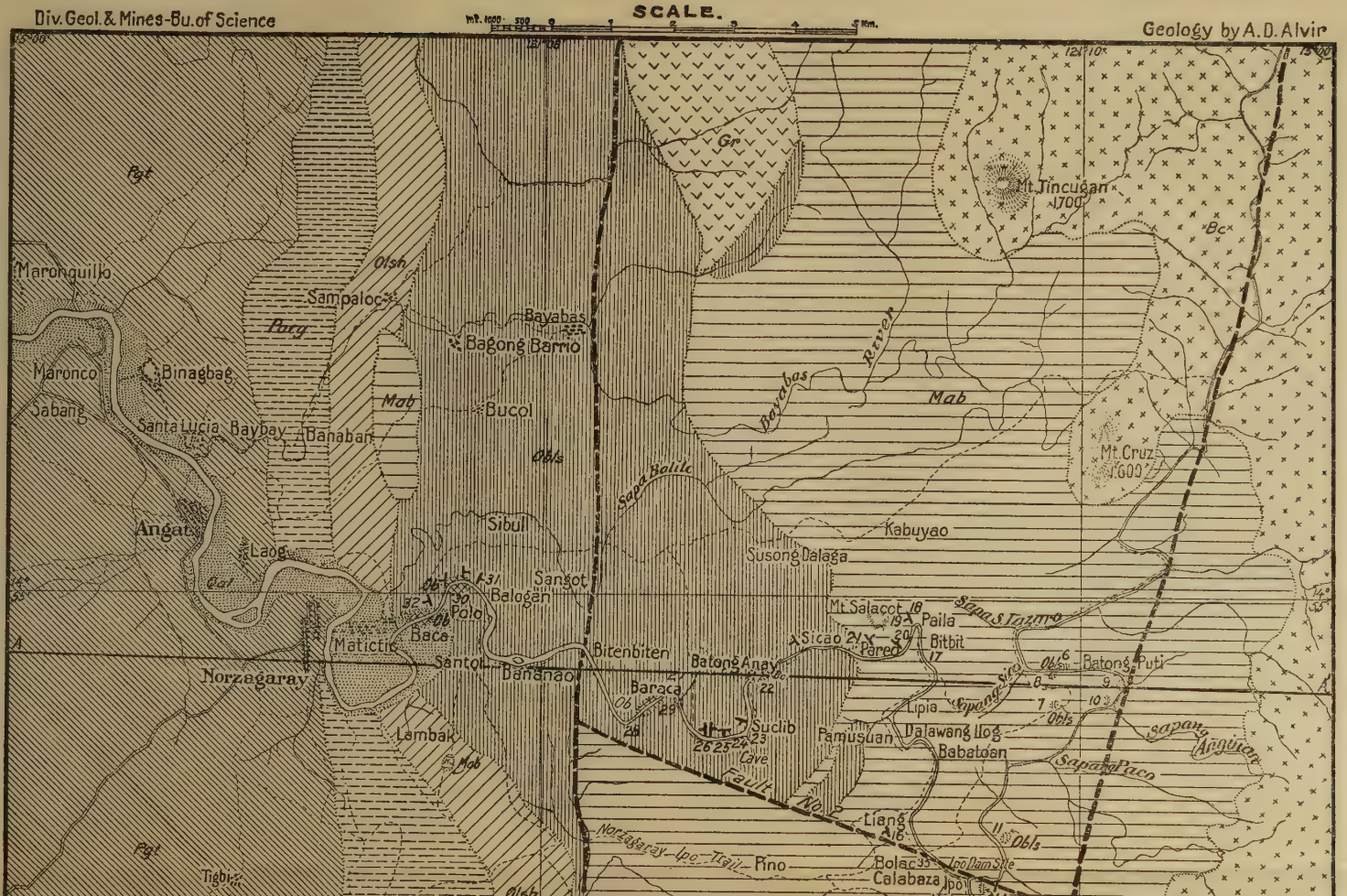


PLATE 2. AREAL GEOLOGIC MAP OF THE ANGAT-NOVALICHES REGION.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Geology by A. D. Alvir
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Sabang
Santa Lucia
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Banaban
Bucol
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Sibul
Kabuyao
Susong Dalaga
Sansot
Balogan
Polo
Baca
Matictic
Santol
Bananao
Norzagaray
Bitenbiten
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Baraca
Suclib
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Sapang Paco
Sapang Angilian
Mt. Salacot
Paila
Sicao
Pared
Bitbit
Batong Puti
Lipia
Liang
Bolac
Calabaza
Ipo
Ipo Dam Site
Pino
Tigbi
Norzagaray—Ipo—Tigbi
Bayabas River
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Pgt
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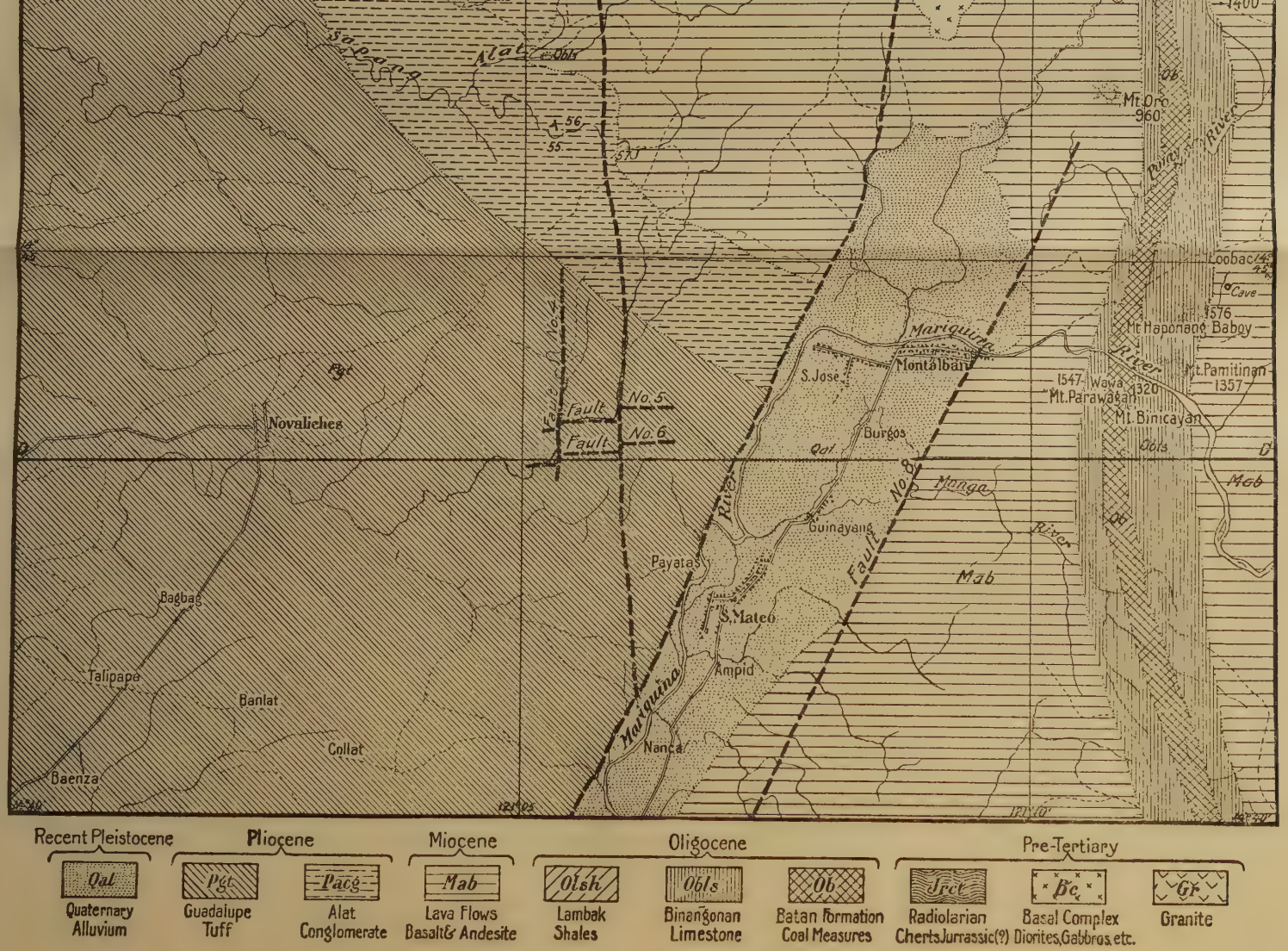
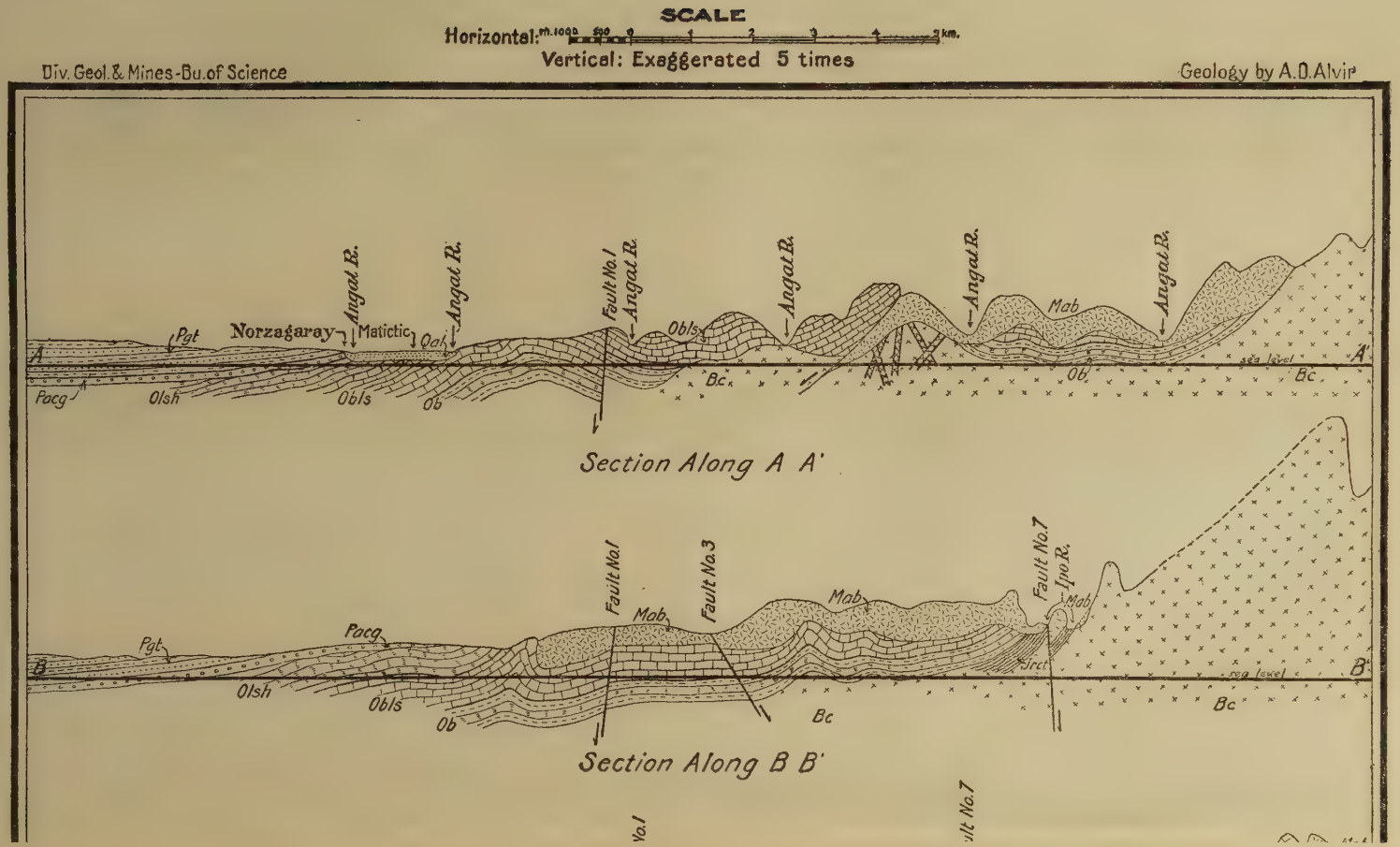


PLATE 2. AREAL GEOLOGIC MAP OF THE ANGAT-NOVALICHES REGION.


SCALE
Horizontal: m. 1000 500 0 1 2 3 4 5 km.
Vertical: Exaggerated 5 times
Div. Geol. & Mines-Bu. of Science
Geology by A.D. Alvir
Angat R.
Fault No.1
Angat R.
Angat R.
Angat R.
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Pgt
Norzagaray
Matictic
Qal
Mab
A
A'
Pacg
Olsh
Obls
Ob
Bc
sea level
Section Along A A'
Fault No.1
Fault No.3
Fault No.7
Ipo R.
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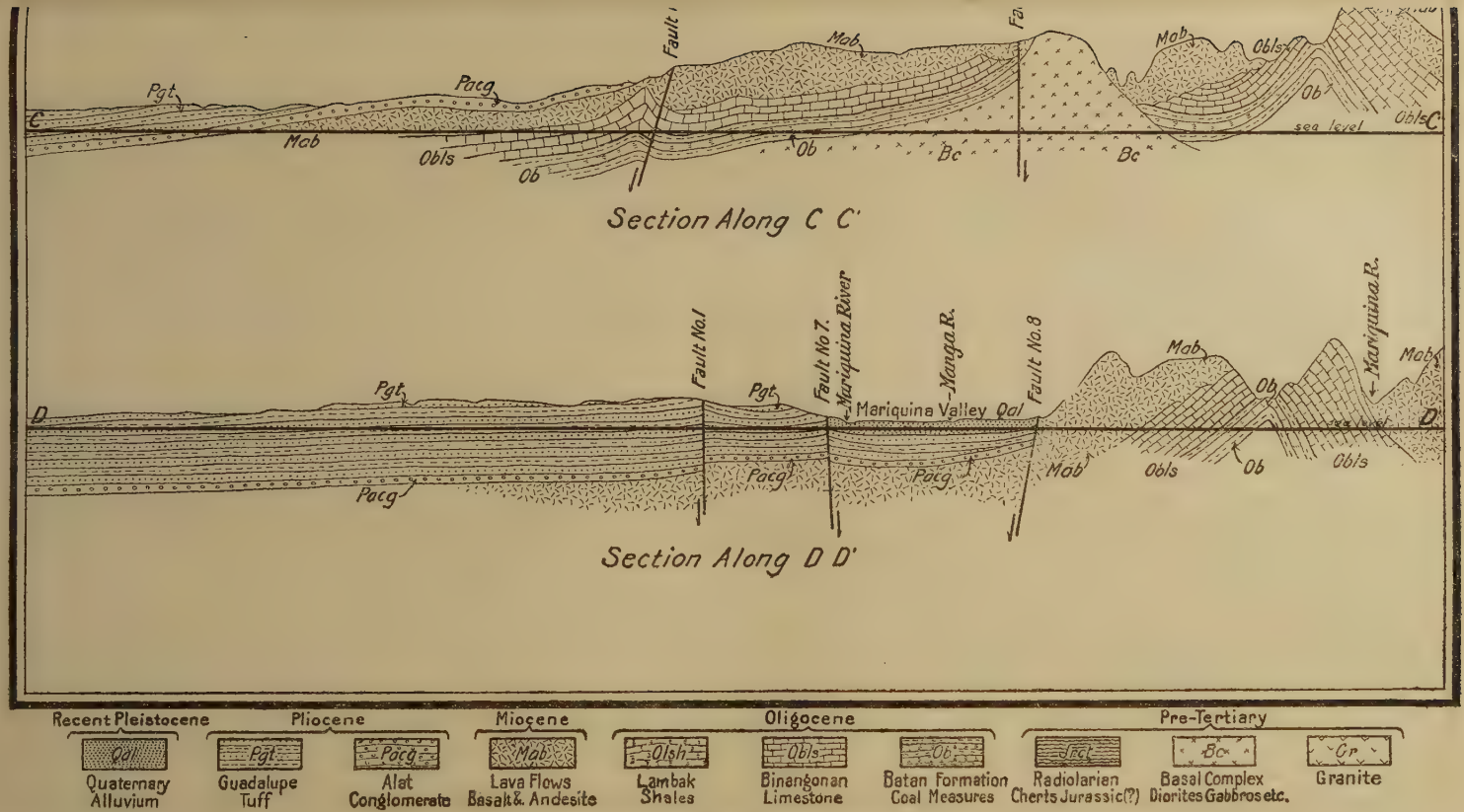
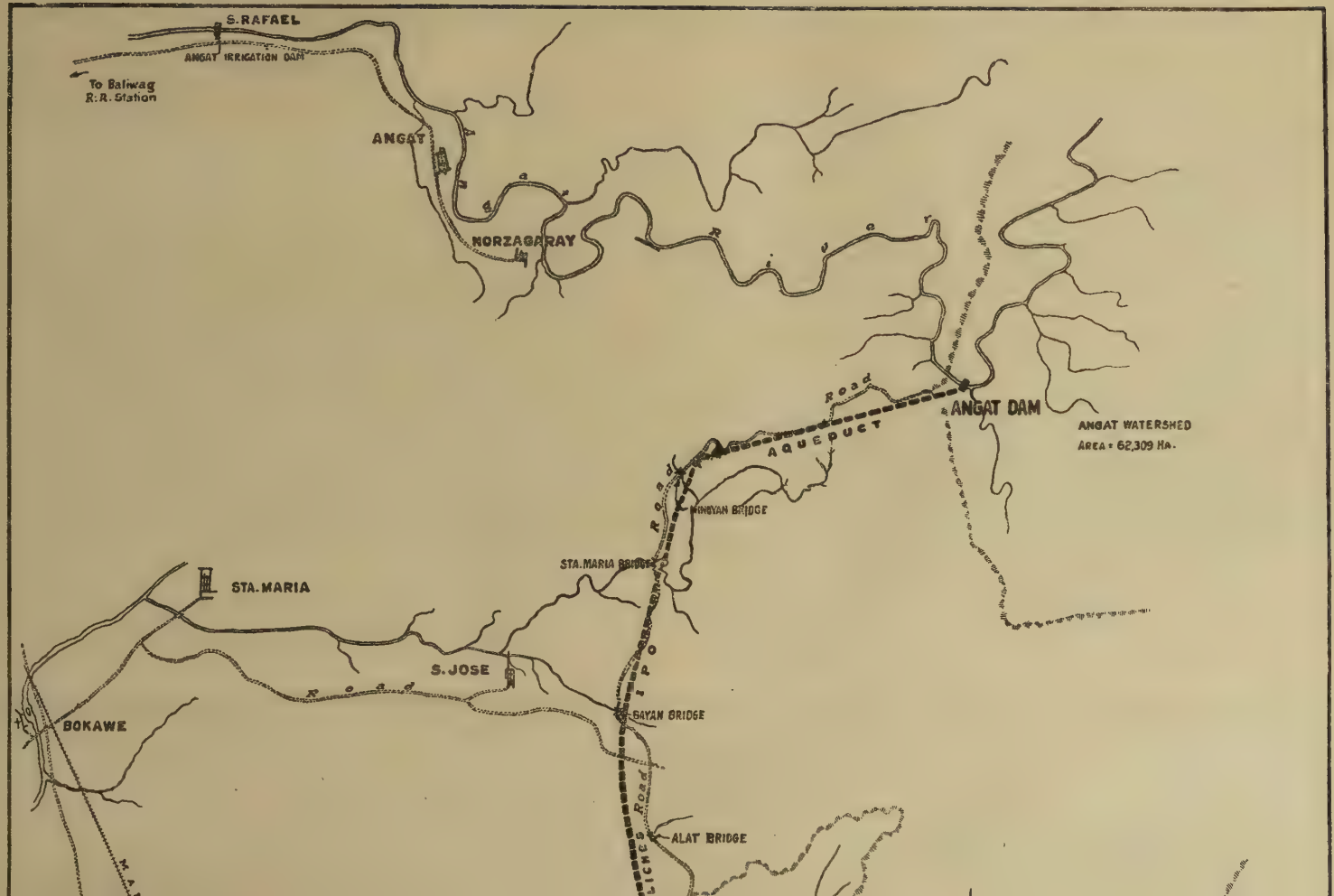
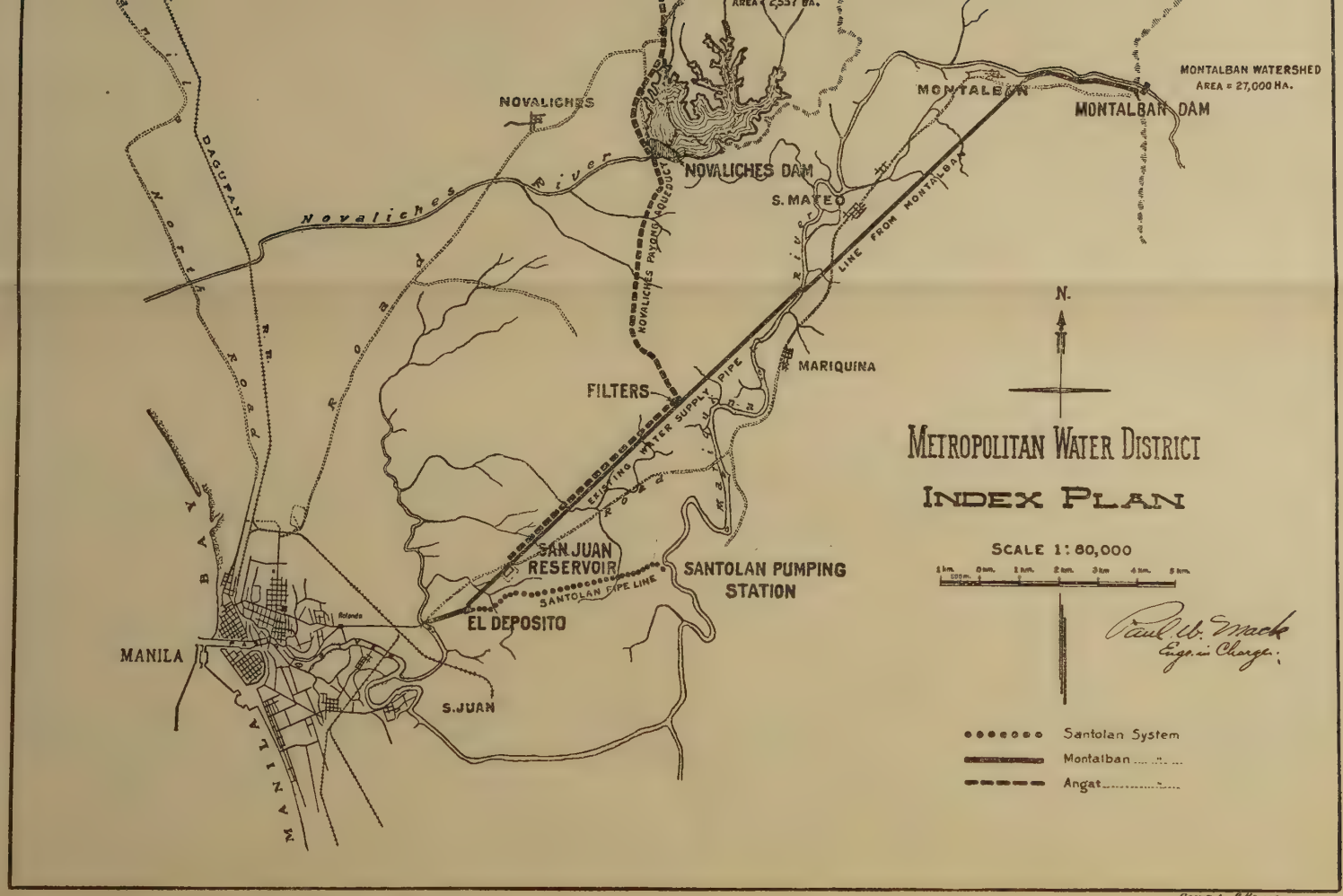


PLATE 3. GEOLOGIC CROSS SECTIONS OF THE ANGAT-NOVALICHES REGION.


S. RAFAEL
ANGAT IRRIGATION DAM
To Baliwag
R. R. Station
ANGAT
NORZAGARAY
ANGAT DAM
ANGAT WATERSHED
AREA = 62,309 Ha.
AQUEDUCT
Road
MINYAN BRIDGE
STA. MARIA BRIDGE
STA. MARIA
S. JOSE
Road
BOKAWE
GAYAN BRIDGE
ALAT BRIDGE
Road



Drawn by R. Nicolas

PLATE 4. THE WATERWORKS PROJECT OF THE METROPOLITAN WATER DISTRICT IN THE ANGAT–NOVALICHES REGION.

PLATE 5. VIEW NORTHEAST FROM THE RAILROAD DEPOT AT MONTALBAN.

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PLATE 6.

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PLATE 7.

PLATE 8. THE FAU

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CARPS OF MARIQUINA VALLEY.

1

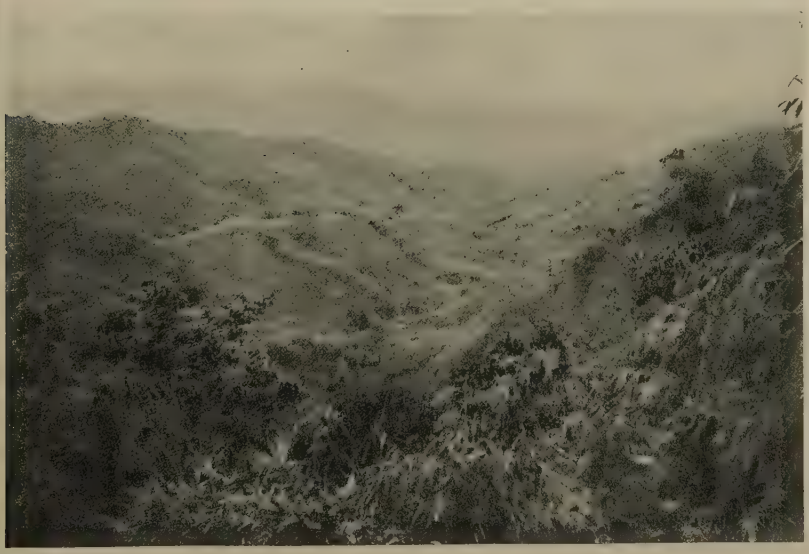

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PLATE 9.

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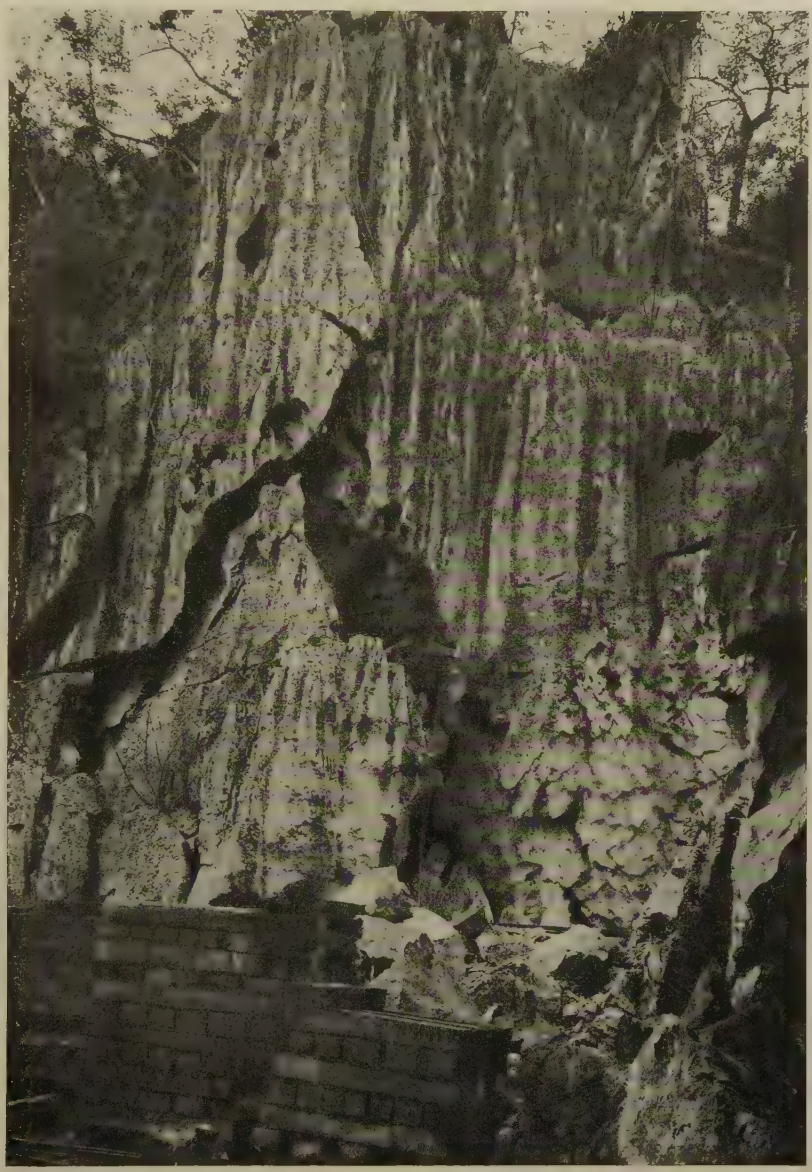
PLATE 9.



Binangonan limestone outcrop at Bicti, showing the broken character of the rock and the rain solution channels.

PLATE 10.

1

2

PLATE 11.

1

2

PLATE 12.

1

2

PLATE 13.

1

2

PLATE 14.

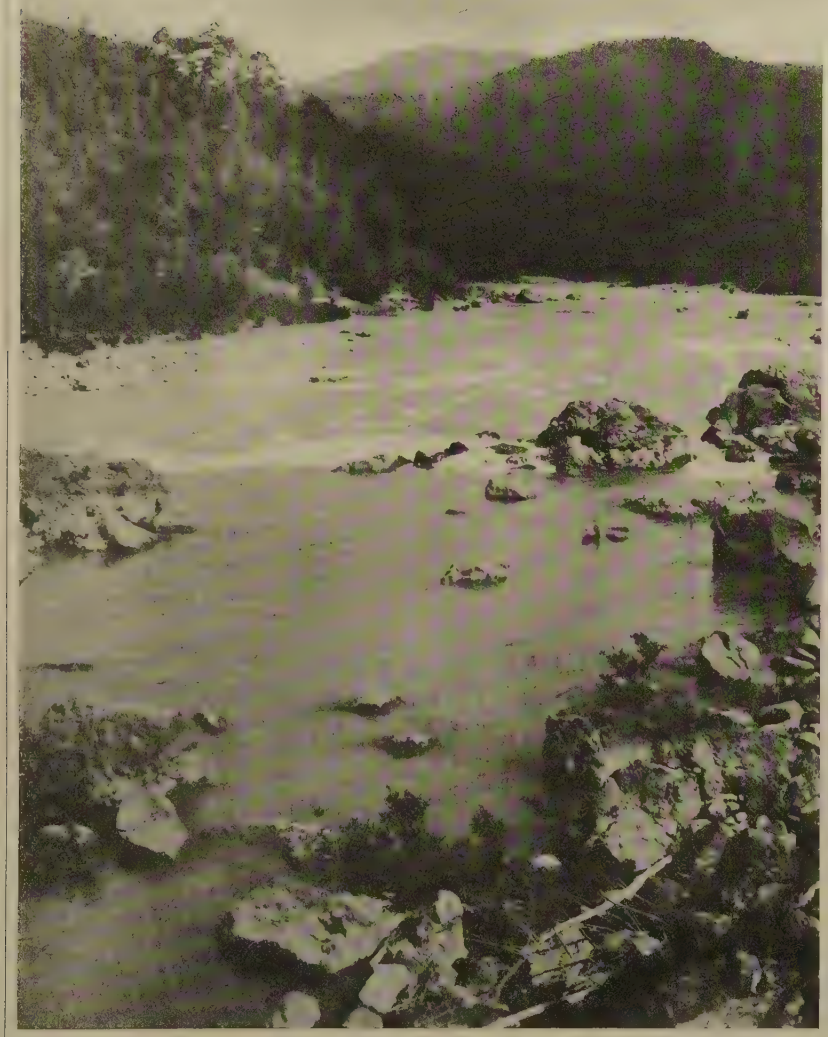


PLATE 15. THE IPO DAM SITE, ON ANGAT RIVER, LOOKING UPSTREAM.

1

2

PLATE 16.

PLATE 17. INTERIOR OF A CAVE AT MONTALBAN.

1

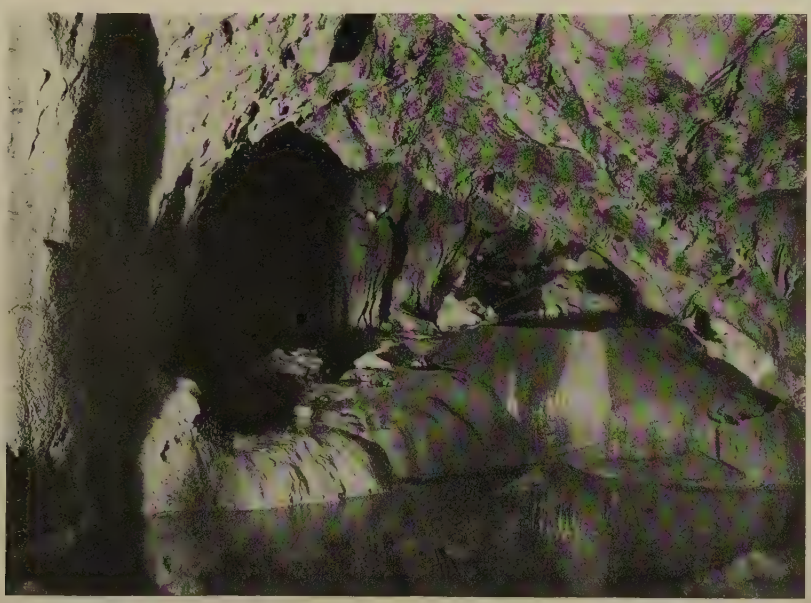


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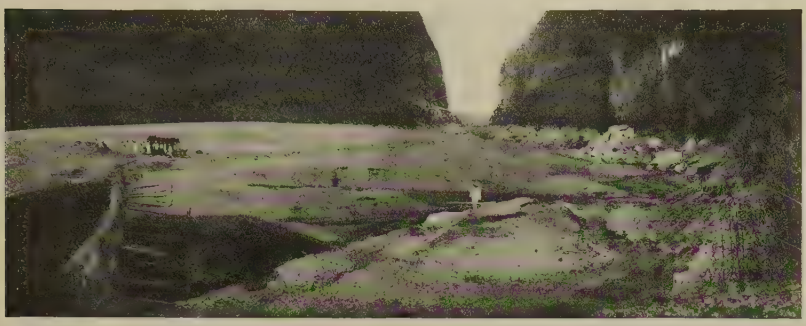
PLATE 18.



1

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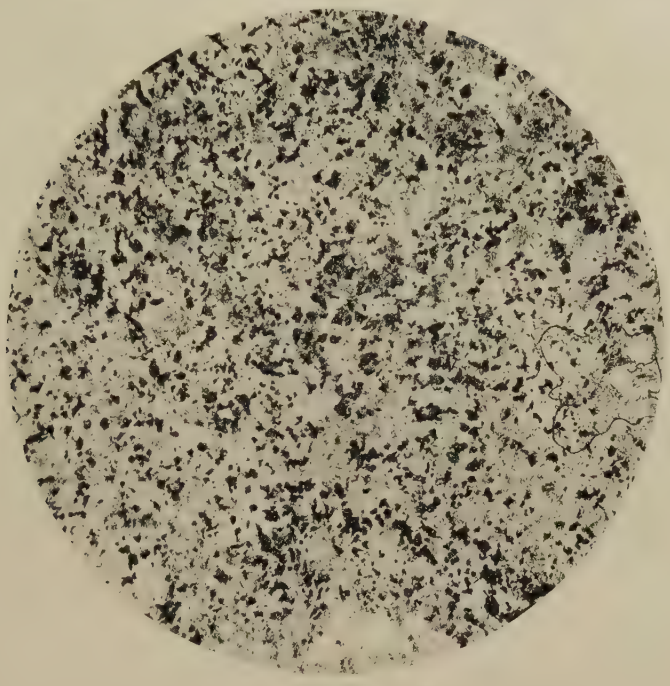

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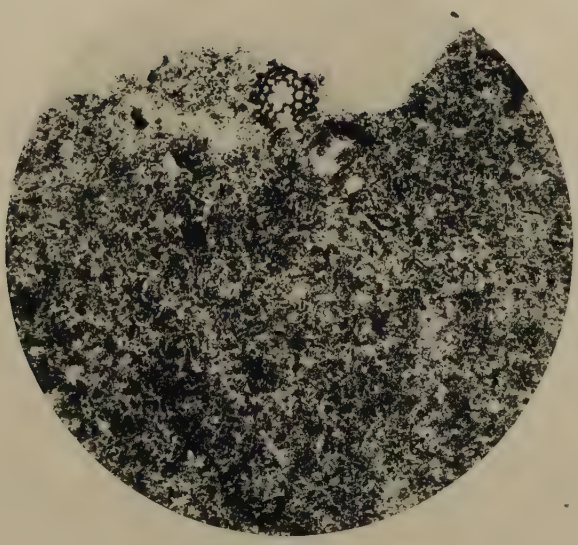

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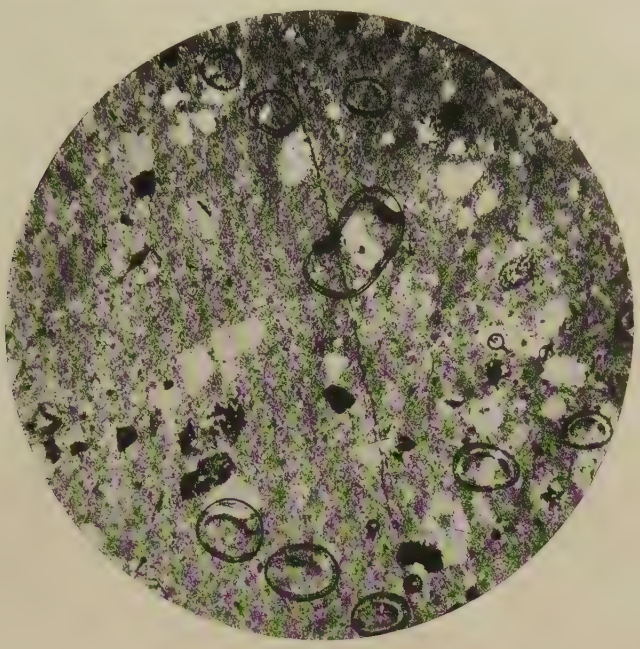
PLATE 20.



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2

PLATE 21.

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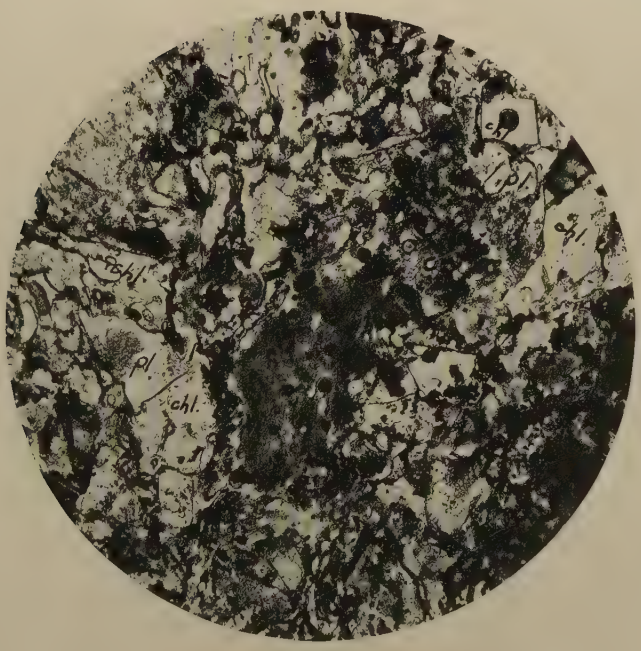

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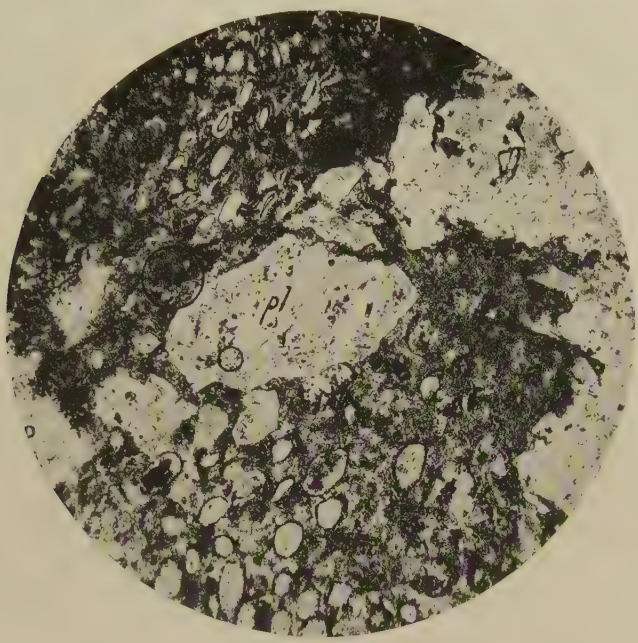

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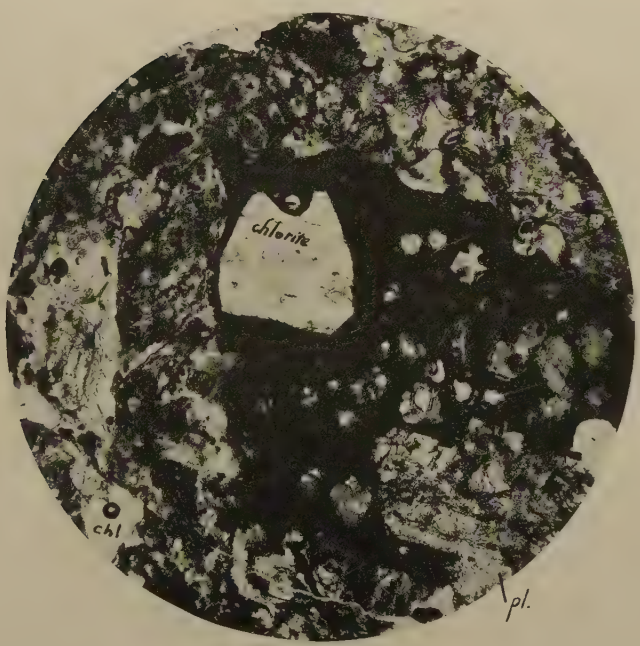

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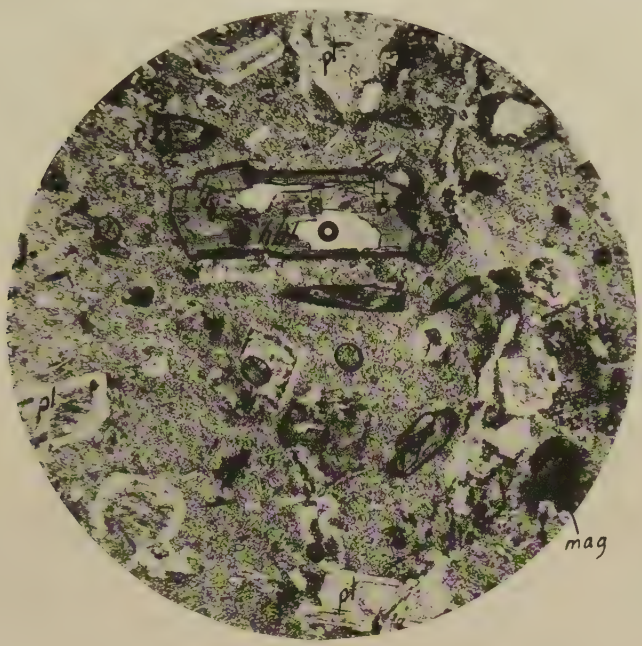

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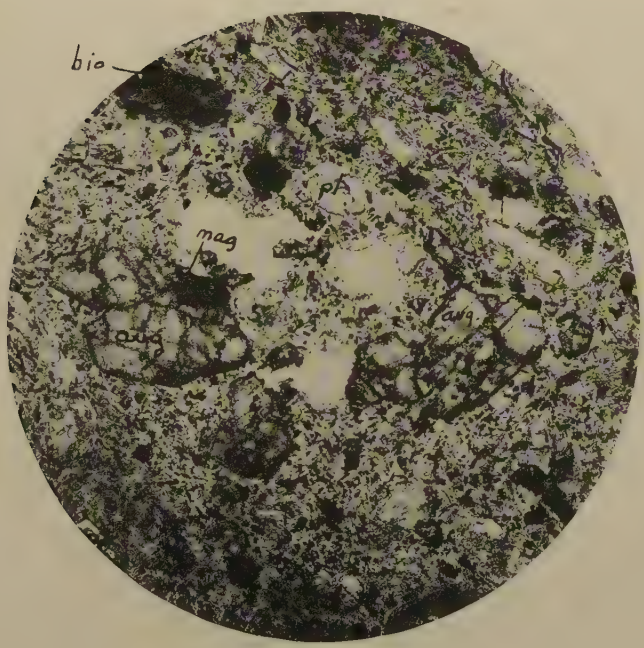

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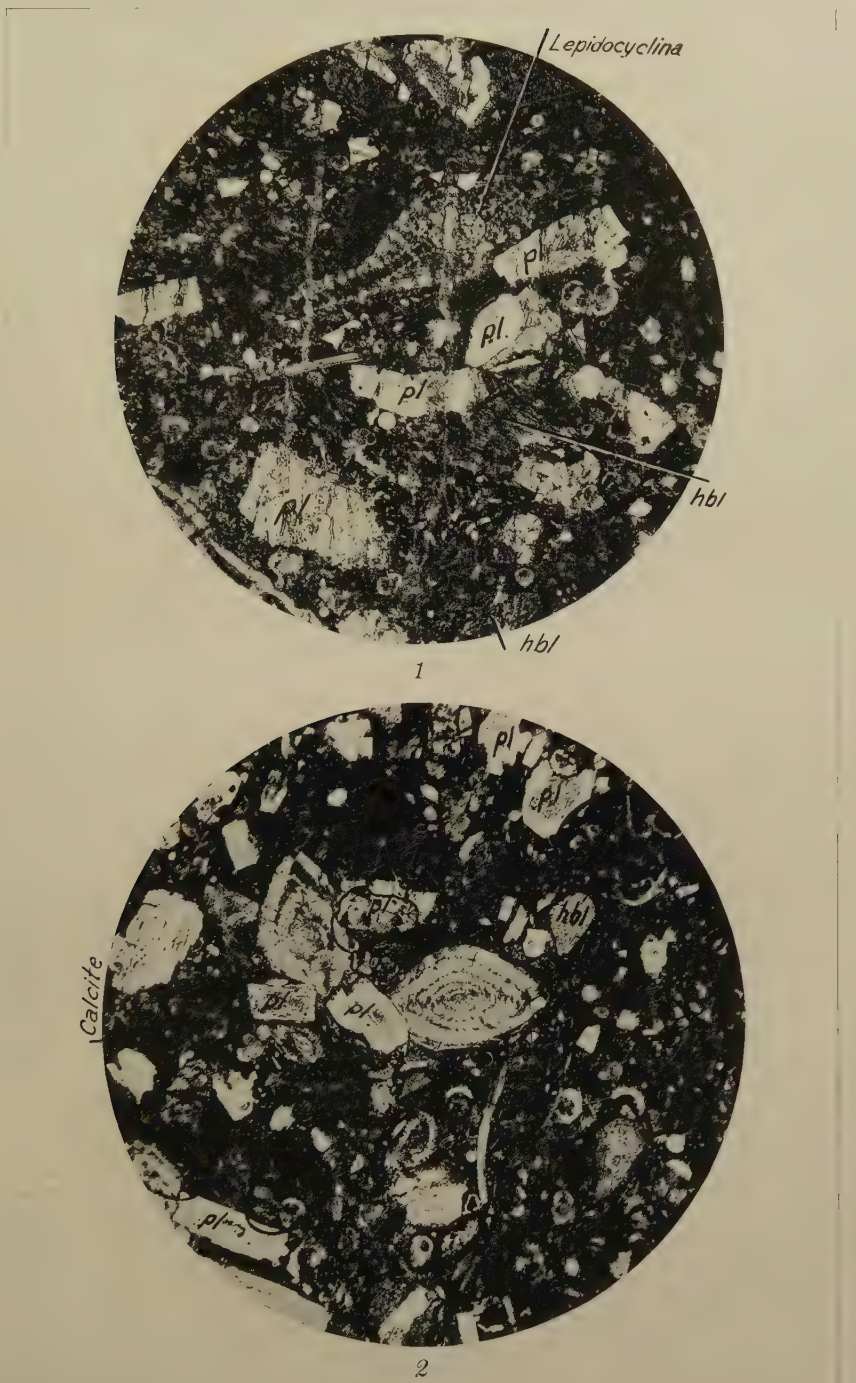

PLATE 25.

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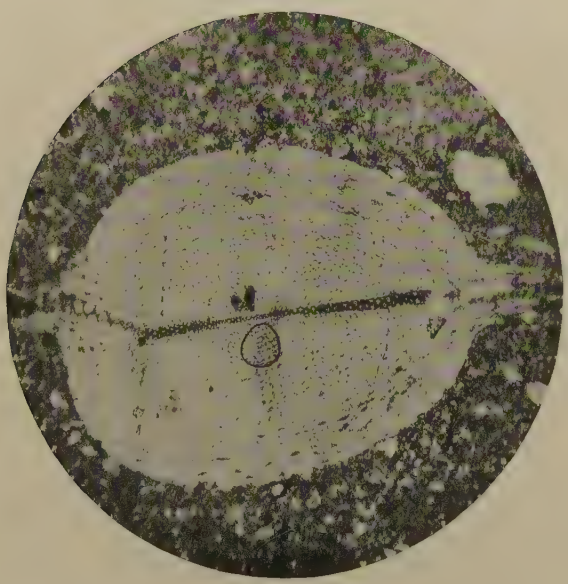

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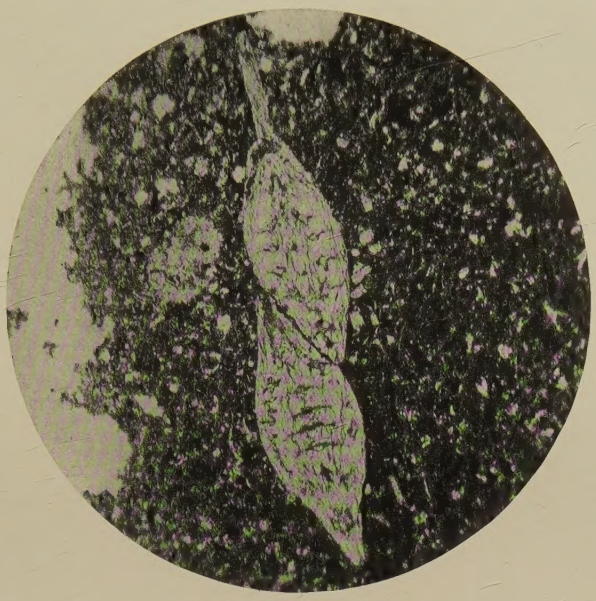
PLATE 26.



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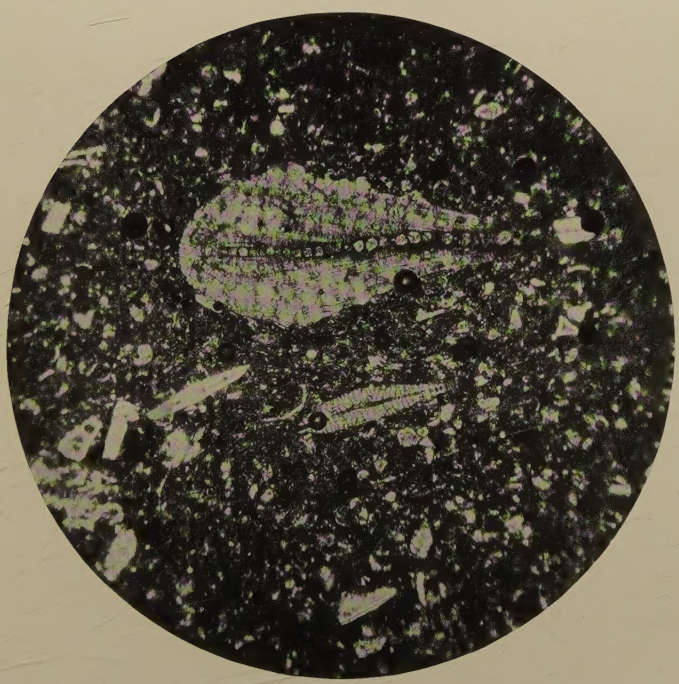

2

PLATE 27.

PLATE 28. MONTALBAN GAP.